Appendix B: Residential Construction

Page

B.1 Example Performance Targets and Efficiency Packages Greensburg, Kansas

Ren Anderson
National Renewable Energy Laboratory

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

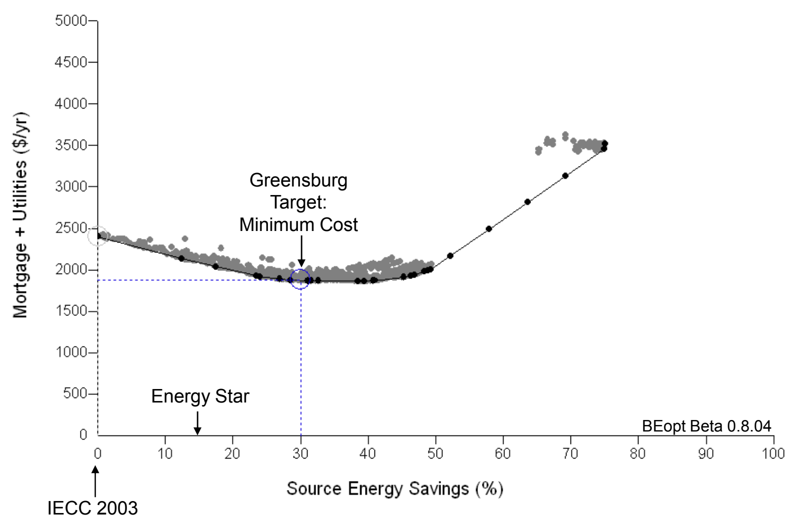
Mixed Humid Climate Region

Example Performance Targets and Efficiency Packages Greensburg, Kansas

Dr. Ren Anderson, NREL

NREL is operated by Midwest Research Institute • Battelle

30% Savings Target: Greensburg



(2000 ft2, 2-story, 16% window to floor area ratio), unconditioned basement

Example: Greensburg 30% Efficiency Package[1]

- 2x6 + R-19 batts (R14 wall assembly)
- R40 ceiling assembly
- R10 basement
- .0002 SLA (4 ACH_{50})
- Low e/low SHGC glazing (0.3 U-value, 0.37 SHGC)
- 50% CFL Lighting
- SEER 14 AC
- AFUE 90+ furnace
- Premium gas hot water, EF 0.61
- Tight ducts (Mastic, 5% Leakage), R-8
- BA QA (moisture control, …)

Estimated cost increase relative to standard home[2,3]: +$1.25-$2.00/ft2

Notes:
1. Equivalent packages may be substituted, based on specific builder preferences
2. Does not include costs associated with builder/contractor training and changes in business practices.
3. Incremental costs evaluated relative to minimum IECC 2003

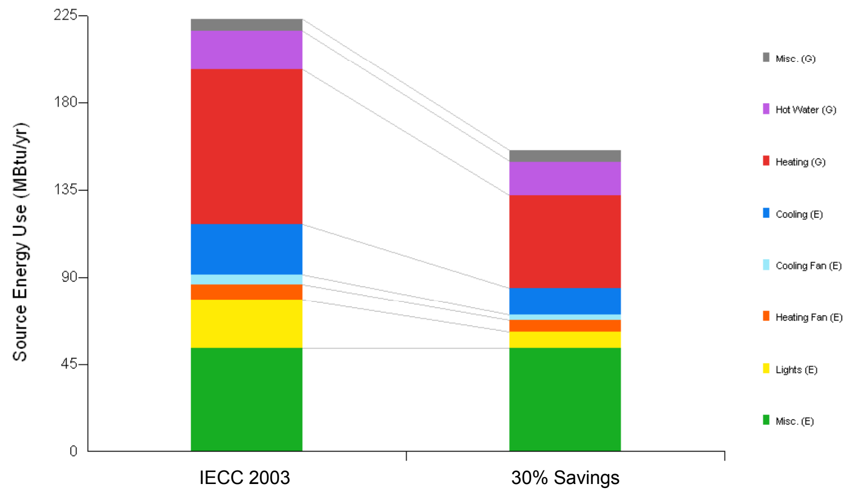
Estimated Annual Cost Savings: 30% Energy Savings Target

	Greensburg
Estimated Incremental First Cost Relative to Standard Practice[1]	$4,000
Annual Amortized Cost 7%, 30Year mortgage[2]	$211
Estimated Annual Utility Bill Savings	$723
Net Annual Savings	**$512**

(2000 ft2, 2-story, 16% window to floor area ratio, unconditioned basement)

[1]Evaluated relative to minimum IECC 2003
[2] Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.

Estimated Annual Energy Savings by End Use: 30% Target



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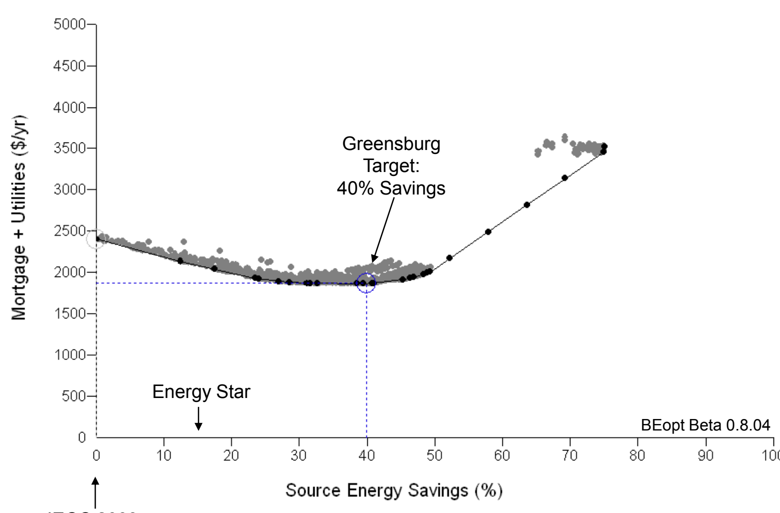
40% Savings Target: Greensburg



IECC 2003

(2000 ft2, 2-story, 16% window to floor area ratio, unconditioned basement)

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Example: Greensburg 40% Efficiency Package[1]

- 2x6 + R-21 batts (R15 wall assembly)
- R50 ceiling assembly
- R10 basement
- .0002 SLA (4 ACH_{50})
- Low e/low SHGC glazing, Argon Fill (0.28 U-value, 0.37 SHGC)
- 80% CFL Lighting
- SEER 18 AC
- AFUE 90+ furnace
- Premium gas hot water, EF 0.61
- Tight ducts (Mastic, 5% Leakage), R-8
- BA QA (moisture control, …)

Estimated cost increase relative to standard home[2,3]: +$3.00-$4.00/ft2

Notes:
1. Equivalent packages may be substituted, based on specific builder preferences
2. Does not include costs associated with builder/contractor training and changes in business practices.
3. Incremental costs evaluated relative to minimum IECC 2003

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Estimated Annual Costs: 40% Efficiency Target

	Greensburg
Estimated Incremental First Cost Relative to Standard Practice[1,2]	$7,000
Annual Amortized Cost 7%, 30 Year mortgage[3]	$411
Annual Utility Bill Savings	$919
Net Annual Savings	**$508**

(2000 ft2, 2-story, 16% window to floor area ratio), unconditioned basement

[1]Evaluated relative to minimum IECC 2003. Cost does not include impact of $2000 tax credit.
[2]Qualifies for federal new home tax credit
[3]Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.

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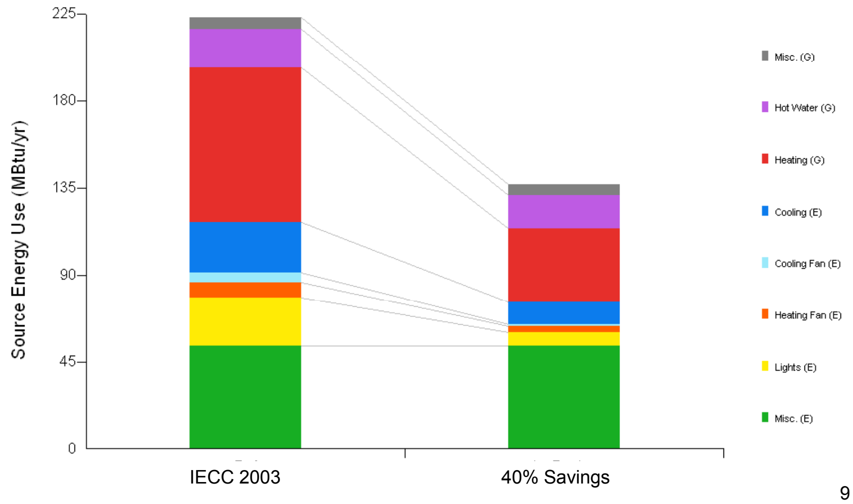
Estimated Annual Energy Savings by End Use: 40% Target



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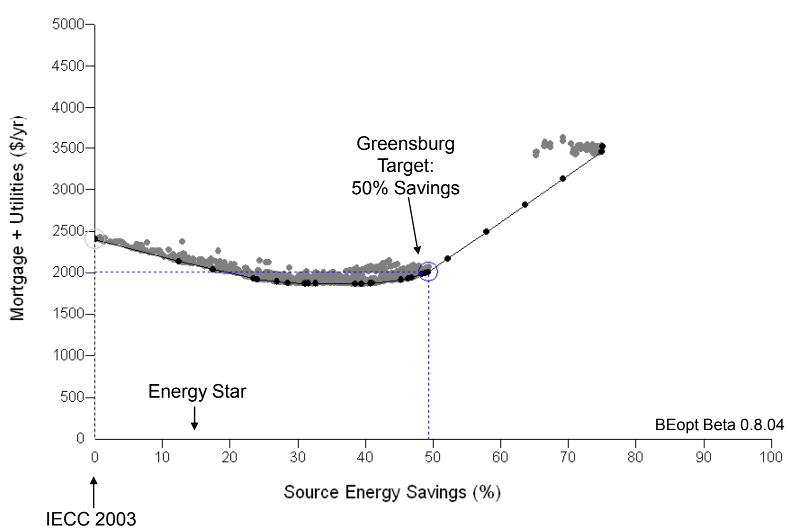
50% Savings Target: Greensburg



(2000 ft2, 2-story, 16% window to floor area ratio, unconditioned basement)

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Example: Greensburg 50% Efficiency Package[1]

- 2x6 + R-19 batts+ foam sheathing (R22 wall assembly)
- R50 ceiling assembly
- R10 basement
- .0001 SLA (2 ACH_{50})
- Low e/low SHGC glazing, Argon Fill (0.28 U-value, 0.37 SHGC)
- 80% CFL Lighting
- SEER 18 AC
- AFUE 90+ furnace
- Gas tankless hot water, EF 0.8+
- Tight ducts (Mastic, 5% Leakage), in conditioned space
- Energy Star Appliances
- BA QA (moisture control, …)

Estimated cost increase relative to standard home[2,3]: +$6.00-$8.00/ft2

Notes:
1. Equivalent packages may be substituted, based on specific builder preferences
2. Does not include costs associated with builder/contractor training and changes in business practices.
3. Incremental costs evaluated relative to minimum IECC 2003

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Estimated Annual Costs: 50% Efficiency Target

	Greensburg
Estimated Incremental First Cost Relative to Standard Practice[1,2]	$13,000
Annual Amortized Cost 7%, 30Year mortgage[3]	$706
Annual Utility Bill Savings	$1162
Net Annual Savings	**$456**

(2000 ft2, 2-story, 16% window to floor area ratio), unconditioned basement

[1]Evaluated relative to minimum IECC 2003
[2]Qualifies for federal new home tax credit
[3]Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.

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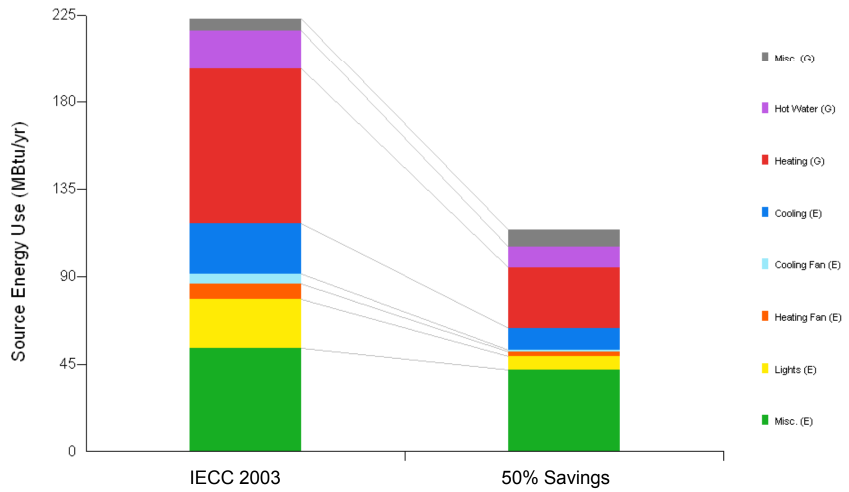
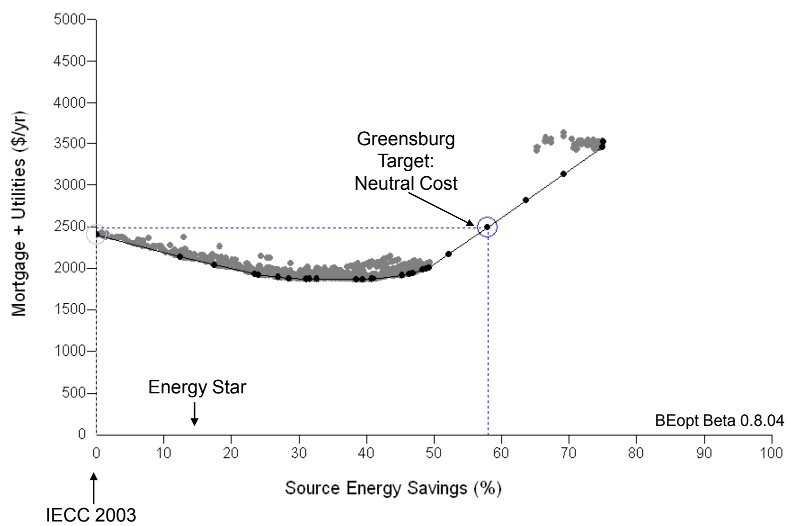
Estimated Annual Energy Savings by End Use: 50% Target



Neutral Cost Point: Greensburg



(2000 ft2, 2-story, 16% window to floor area ratio, unconditioned basement)

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Example: Greensburg Neutral Cost Package[1]

- R22 wall assembly (2x6 + R-19 batts+ foam sheathing)
- R50 ceiling assembly
- R10 basement
- .0001 SLA (2 ACH_{50})
- Low e/low SHGC glazing, Argon Fill (0.28 U-value, 0.37 SHGC)
- 80% CFL Lighting
- SEER 18 AC
- AFUE 90+ furnace
- Gas tankless hot water, EF 0.8+
- Tight ducts (Mastic, 5% Leakage), in conditioned space
- Energy Star Appliances
- 1.5 kW_{DC} PV System
- BA QA (moisture control, …)

Estimated cost increase relative to standard home[2,3]: +$10.00-$13.00/ft2

Notes:
1. Equivalent packages may be substituted, based on specific builder preferences
2. Does not include costs associated with builder/contractor training and changes in business practices.
3. Incremental costs evaluated relative to minimum IECC 2003

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Estimated Annual Costs: Neutral Cost Target

	Greensburg
Estimated Incremental First Cost Relative to Standard Practice[1,2]	$25,000
Annual Amortized Cost 7%, 30Year mortgage[3]	$1386
Annual Utility Bill Savings	$1386
Net Annual Savings	**$0**

(2000 ft2, 2-story, 16% window to floor area ratio), unconditioned basement

[1]Evaluated relative to minimum IECC 2003
[2]Qualifies for federal new home tax credit
[3]Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.

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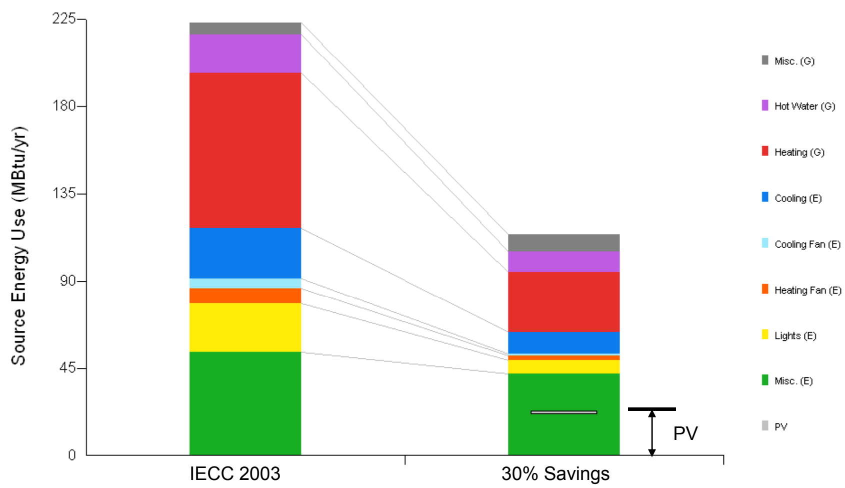
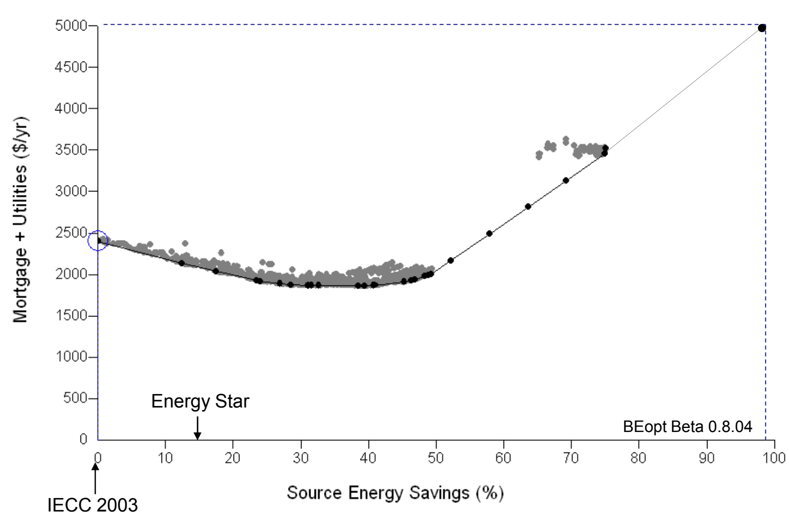
Estimated Annual Energy Savings by End Use: Neutral Cost Target



Net Zero Energy Target: Greensburg



(2000 ft2, 2-story, 16% window to floor area ratio, unconditioned basement)

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Example: Greensburg NZEH Package[1]

- R22 wall assembly (2x6 + R-19 batts+ foam sheathing)
- R50 ceiling assembly
- R10 basement
- .0001 SLA (2 ACH_{50})
- Low e/low SHGC glazing, Argon Fill (0.28 U-value, 0.37 SHGC)
- 80% CFL Lighting
- SEER 18 AC
- AFUE 90+ furnace
- Gas tankless hot water, EF 0.8+
- Tight ducts (Mastic, 5% Leakage), in conditioned space
- Energy Star Appliances
- 7 kW_{DC} PV System and solar hot water system
- BA QA (moisture control, …)

Estimated cost increase relative to standard home[2,3]: +$35.00-$40.00/ft2

Notes:
1. Equivalent packages may be substituted, based on specific builder preferences
2. Does not include costs associated with builder/contractor training and changes in business practices.
3. Incremental costs evaluated relative to minimum IECC 2003

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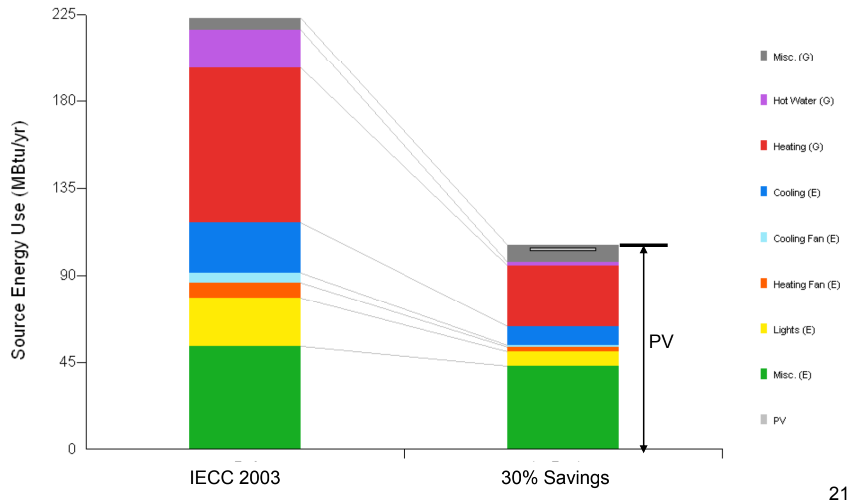
Estimated Annual Costs: Net Zero Energy Target

	Greensburg
Estimated Incremental First Cost Relative to Standard Practice[1,2]	$69,000
Annual Amortized Cost 7%, 30Year mortgage[2]	$4102
Annual Utility Bill Savings	$2306
Net Annual Savings	**-$1796**

(2000 ft2, 2-story, 16% window to floor area ratio), unconditioned basement

[1]Evaluated relative to minimum IECC 2003
[2]Qualifies for federal new home tax credit
[3] Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.

Estimated Annual Energy Savings by End Use: Net Zero Energy Target



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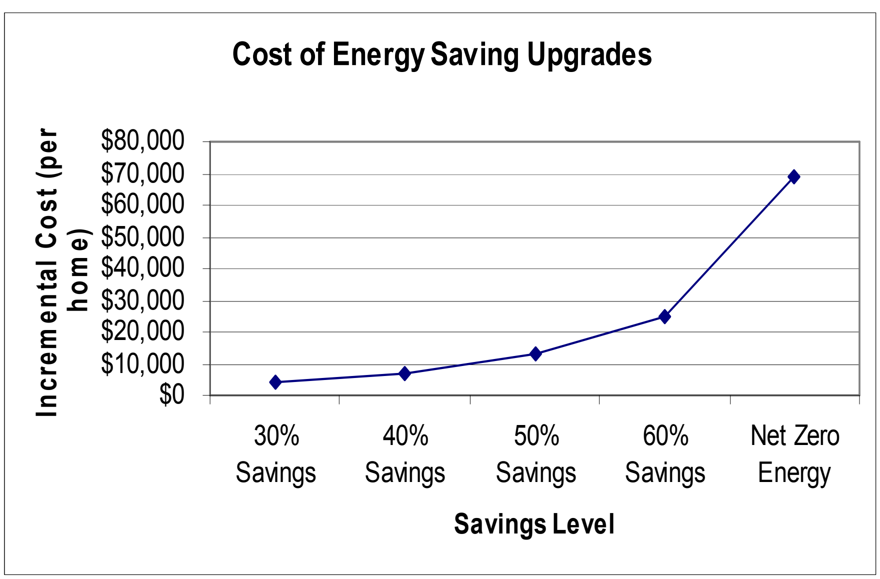

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Innovation for Our Energy Future

B.2 Why Build an Energy Efficient Home?

Ren Anderson
National Renewable Energy Laboratory

Why Build an Energy Efficient Home?..........

It Saves You Money!

Upgraded Energy Savings Levels			
For a typical 2,000 sqft. home:	**Base Efficiency**	**High Efficiency**	**Premium Efficiency**
Estimated Incremental First Cost	$4,000	$7,000	$13,000
Savings on Monthly Utility Bill[1]	$60.25	$76.58	$96.83
Increase in Monthly Mortgage Payment[2]	$17.58	$34.25	$58.83
Net Monthly Savings	**$42.67**	**$42.33**	**$38.00**

[1] Evaluated relative to current Building Code - IECC 2003.
[2] Based on a 30 year mortgage at 7% APR with an increase in loan value of $4,000 for the 30% option (Base), $7,000 for the 40% option (High), and $13,000 for the 50% option (Premium).

You also get:

- Increased Durability
- Increased Comfort




What is Required to Own an Energy Efficient Home?.....

Simple Efficiency Upgrades Provided by Your Builder!

Energy Efficiency Upgrades

	Basic Efficiency Package	High Efficiency Package	Premium Efficiency Package
Insulation			
Walls	R-19	R-21	R-19 + R-5 Foam
Roof	R-40	R-50	R-50
Basement	R-10	R-10	R-10
Windows	Double-glazed, low-e	Double-glazed, low-e, argon-filled	Double-glazed, low-e, argon-filled
U-Value	0.30	0.28	0.28
Solar Rating	0.37	0.37	0.37
Lighting % Compact Fluorescents	50%	80%	80%
Heating Efficiency Rating	90+%	90+%	90+%
Air Conditioning Efficiency Rating	14	18	18
Appliances	Standard	Standard	ENERGY STAR
Water Heater	Tank - gas	Tank - gas	Tankless - gas
Energy Factor	0.61	0.61	0.80
Ventilation	Exhaust	Supply	Balanced

For more information, contact: Greensburg GreenTown (620-549-3275 or 620-723-2790) or Department of Energy / National Renewable Energy Laboratory representatives (620-210-0281)

B.3 Recommendation: Greensburg, Kansas, should Adopt the Best Green Housing Requirements in the United States

Ren Anderson
National Renewable Energy Laboratory

Requirement: All new residential construction is encouraged to be designed, contracted and built to achieve whole-house energy savings of at least 40% relative to minimum code using a "green building" approach. All existing residences and housing projects are encouraged to target maximum cost-effective energy savings

"Green building" is a whole-systems approach utilizing design and building techniques to minimize environmental impact and reduce the energy consumption and utility costs of a building while contributing to the health of its occupants and building durability. This requirement includes:

- Forty percent energy cost savings compared to a typical building built to code
- A healthy indoor environment
- Reduction in water use compared to a typical building
- Use of renewable energy generation wherever appropriate
- Use of locally available and recycled materials while minimizing construction waste
- Reducing the overall environmental impact from the site.

B.3.1. What are the Benefits of City Leadership Setting this Requirement?

By adopting this goal and green building approach the city will:

- Reduce homeowner utility costs
- Reduce peak electric demand and backup power requirements
- Substantially reduce negative environmental impacts and increase home durability
- Enhance building value and marketability
- Increase homeowner comfort
- Set the example for other housing projects and homeowners in Greensburg
- Receive extensive media coverage potentially leading to economic growth.

B.3.2 Cost Impacts Are Understood

- The best designed larger buildings have been documented to have NO increase in cost.
- Cost increases may be 3%-10% for Greensburg's smaller buildings, but will be more than compensated by lower utility bills.

12-03-07

B.4 High Performance Housing

Produced by: Building Science Corporation
for the DOE Building America Program

a. Foundations and Ground Water Control

b. Passive Radon Mitigation System

c. Controlled Ventilation System

d. Ductwork in Conditioned Space

e. Transfer Ducts and Grilles

f. Duct Sealing

g. Sealed Combustion Water Heaters

h. Basement Insulation

i. Wall Bracing Requirements for Insulating Sheathing

j. Insulating Sheathing Vapor Retarder Requirements

k. Cladding Attachment over Insulating Sheathing

l. Conditioned Attics

High Performance Housing — **Information Sheet 1**
for Greensburg, Kansas
Foundations and Groundwater Control

Water managed foundation systems rely on two fundamental principles:

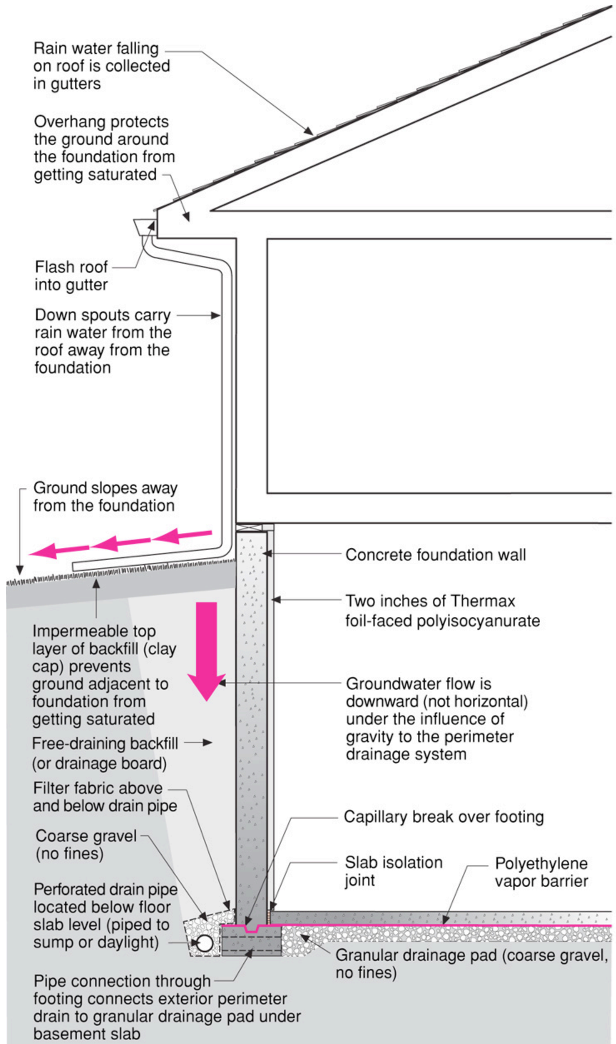
- keep rain water away from the foundation wall perimeter
- drain groundwater with sub-grade perimeter footing drains before it gets to the foundation wall

Water managed foundation systems are different from waterproofing systems. Waterproofing relies on creating a watertight barrier without holes. It can't be done. Even boats need pumps. Water managed foundation systems prevent the buildup of water against foundation walls, thereby eliminating hydrostatic pressure. No pressure, no force to push water through a hole. Remember, we know the foundation wall will have holes.

Mixing control joints with water management is a fundamental requirement for functional foundation systems that provide an extended useful service life. Dampproofing should not be confused with waterproofing. Dampproofing protects foundation materials from absorbing ground moisture by capillarity. Dampproofing is not intended to resist groundwater forces (hydrostatic pressure). If water management is used, waterproofing is not necessary. However, control of capillary water is still required (dampproofing). Dampproofing is typically provided by coating the exterior of a concrete foundation wall with a tar or bituminous paint or coating.

Draining groundwater away from foundation wall perimeters is typically done with free-draining backfill such as sand, gravel or other water-permeable material, or drainage boards or exterior foundation insulations with drainage properties.

Groundwater Control with Basements



- Keep rain water away from the foundation perimeter
- Drain groundwater away in sub-grade perimeter footing drains before it gets to the foundation wall

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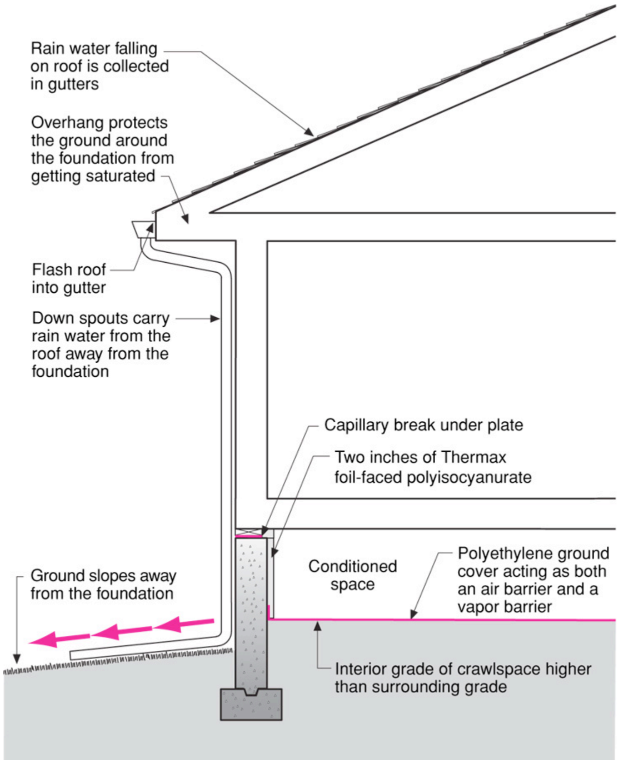
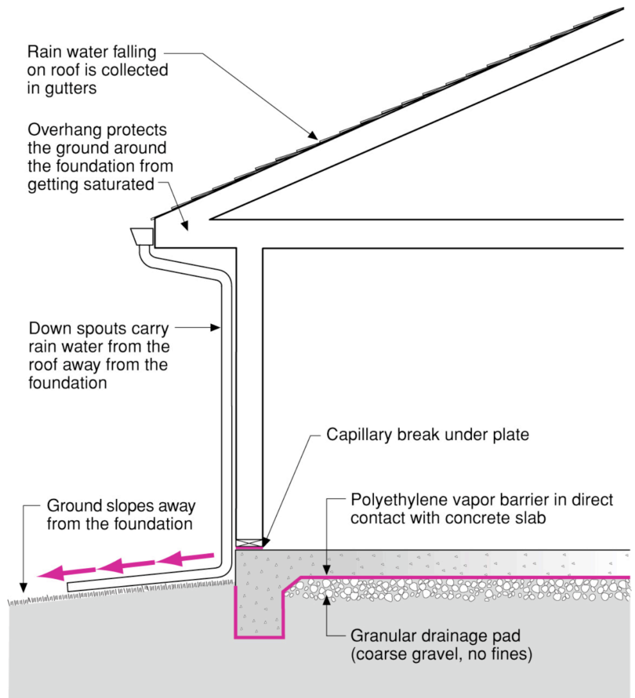
For more information about the Greensburg, Kansas project go to **buildingamerica-greensburg.com**

Groundwater Control with Crawlspaces



- Keep rain water away from the foundation perimeter
- If the interior crawlspace is lower than the exterior grade, a sub-grade perimeter footing drain is necessary as in a basement foundation
- The crawlspace in this configuration is conditioned space; it is part of the "interior" of the building and should be heated, cooled and ventilated as part of the building's heating, cooling and ventilating strategy

Groundwater Control with Slabs



- Keep rain water away from the foundation perimeter
- Do not place sand layer over polyethylene vapor barrier under concrete slab

High Performance Housing — **Information Sheet 10**
for Greensburg, Kansas
Passive Radon Mitigation System

Keeping soil gas (radon, water vapor, herbicides, termiticides, methane, etc.) out of foundations cannot be done by building hole-free foundations because hole-free foundations cannot be built. Soil gas moves through holes due to a pressure difference. Since we cannot eliminate the holes, the only thing we can do is control the pressure.

The granular drainage pad located under concrete slabs can be integrated into a sub-slab ventilation system to control soil gas migration by creating a zone of negative pressure under the slab. A vent pipe connects the sub-slab gravel layer to the exterior through the roof. This "passive" radon mitigation system is illustrated in the figure *Soil Gas Ventilation System—Basement Construction.*

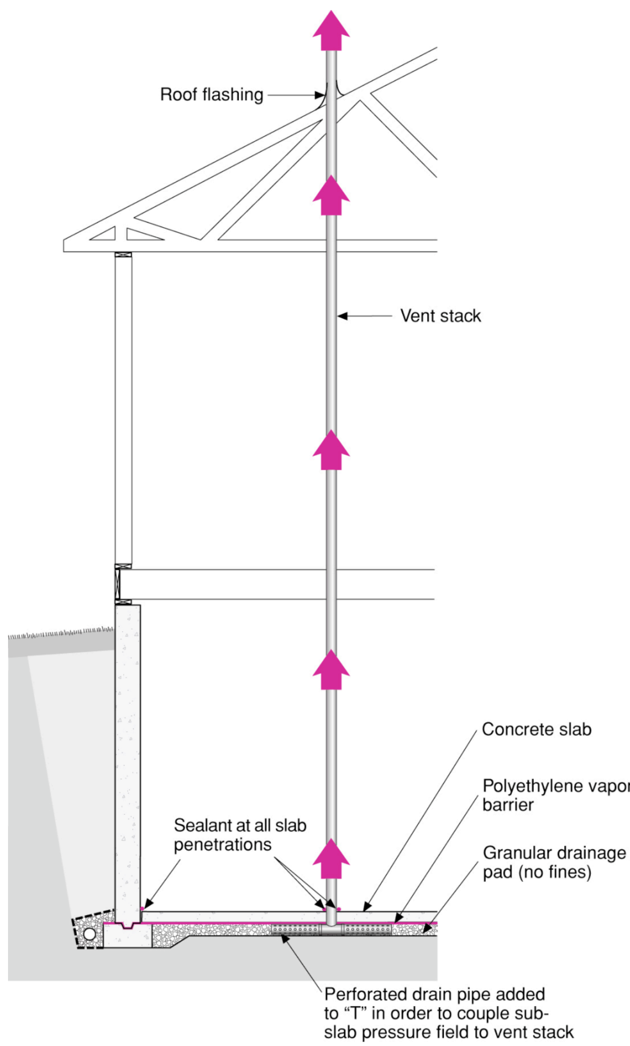
An exhaust fan can be added later, if necessary, to make this an "active" mitigation system.

More information about radon and radon resistance construction can be found on the Environmental Protection Agency's website at: www.epa.gov/iaq/radon/

See also the following EPA documents:

- "Building Radon Out: A Step-by-Step Guide on How to Build Radon-Resistant Homes"
- "Radon Resistant Construction Architectural Drawings"
- "Model Standards and Techniques for Control of Radon in New Residential Buildings"

Soil Gas Ventilation System—Basement Construction



- Granular drainage pad depressurized by active fan located in attic or by passive stack action of warm vent stack located inside heated space
- Avoid offsets or elbows in vent stack to maximize air flow

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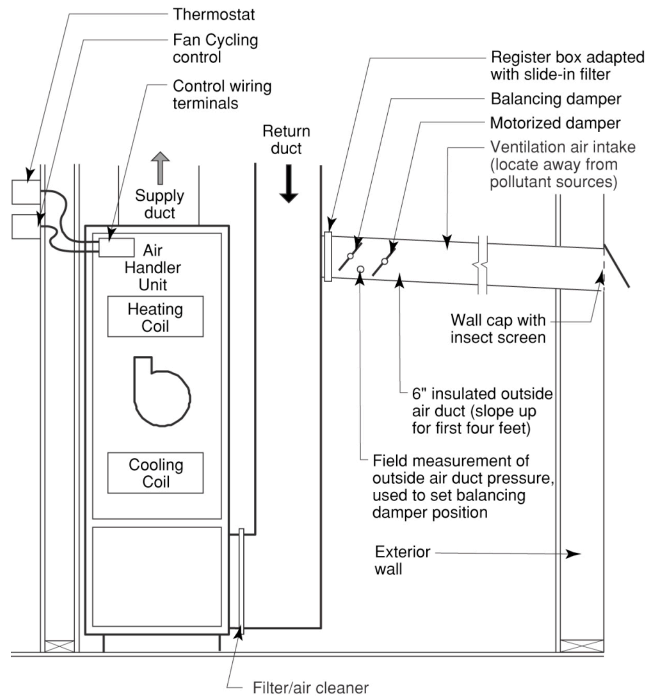
High Performance Housing — **Information Sheet 11**
for Greensburg, Kansas
Controlled Ventilation System

All buildings require controlled mechanical ventilation, or the controlled, purposeful introduction of outdoor air to the conditioned space. Building intentionally leaky buildings and installing operable windows does not provide sufficient outside air in a consistent manner. Building enclosures must be "built tight and then ventilated right." Why? Because before you can control air you must enclose it. Once you eliminate big holes it becomes easy to control air exchange between the inside and the outside.

With a tight building enclosure, both mechanical ventilation and pollutant source control are required to ensure that there is reasonable indoor air quality inside the house. These approaches are shown schematically in figure *Integrated Supply Ventilation System.*

The ventilation system for this house is designed as a central fan integrated system, which is made up of a 6-inch outdoor air intake duct connected to the return side of the air handler. This duct draws outdoor air in to the air distribution system and distributes it to the various rooms in the house. The intake duct has a motorized damper controlled by a fan cycling control to close the damper to prevent over ventilation of the house during times of significant space conditioning demands. An example of the central fan ventilation system with 6-inch motorized damper is shown in figure *Outdoor Air Duct Connected to the Return of the Air Handler.*



- Outside air duct should be insulated and positioned so that there is a fall/slope toward the outside to control any potential interior condensation. Avoid using long lengths of flex duct, which may have a dip and could create a reservoir for condensation
- Motorized damper allows control of ventilation air duty cycle (i.e., run time) separate from air handler duty cycle
- Controller can be mounted on the air handler, or in the main space near the thermostat
- Balancing damper adjusted to provide required flow
- Mixed return air temperatures (return air plus outside air) should not be allowed to drop below 50° Fahrenheit at the design temperature in order to control condensation of combustion gases on heat exchanger surfaces

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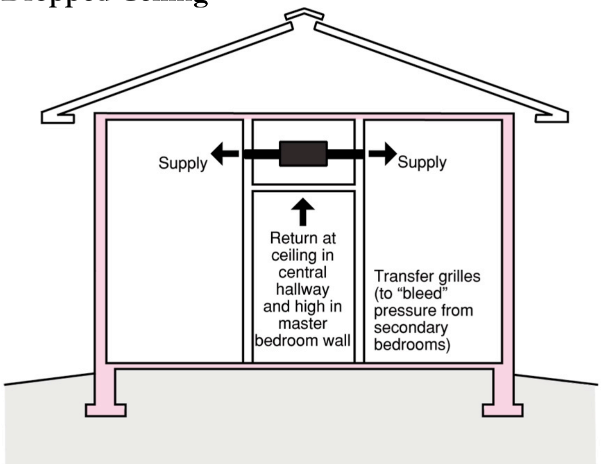
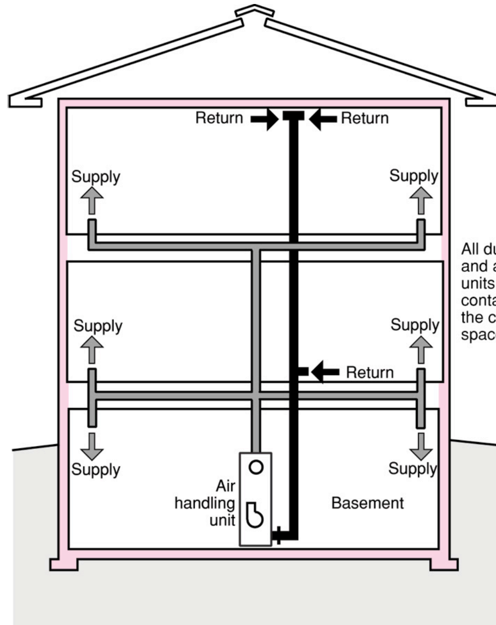
Vented and Unconditioned Attic with a Dropped Ceiling



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

- In this approach, exterior wall heights are typically increased to 9-feet or more leaving hallway ceiling heights at 8-feet
- The air handling unit is located in an interior closet and the supply and return ductwork are located in a dropped hallway
- Transfer grilles "bleed" pressure from secondary bedrooms
- Ductwork does not have to extend to building perimeters when thermally efficient windows (low-E, spectrally selective) and thermally efficient (well-insulated 2x6 frome walls with 2" of insulating sheathing) building enclosure construction is used; throw-type registers should be selected
- Low efficiency gas appliances that are prone to spillage or backdrafting are not recommended in this type of application; heat pumps, heat pump water heaters or sealed combustion furnaces and water heaters should be used
- A hot water-to-air coil in an air handling unit can be used to replace the gas furnace/heat exchanger. The coil can be connected to a sealed combustion (or power vented) water heater located within the conditioned space.
- Ductwork is not located in exterior walls or in the vented attic

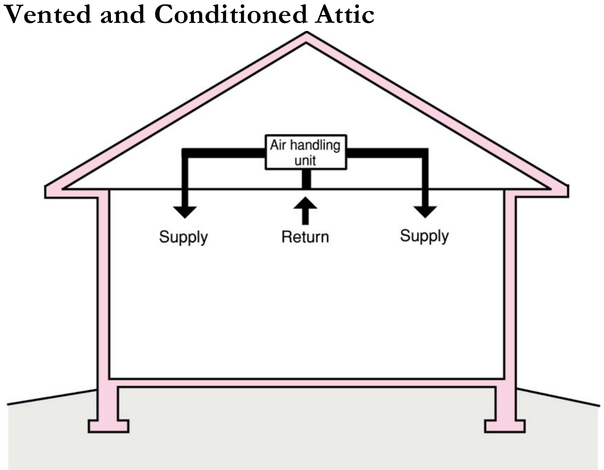
Vented and Unconditioned Attic



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

- The air handling unit is located in a conditioned basement
- Low efficiency gas appliances that are prone to spillage or backdrafting are not recommended in this type of application; heat pumps, heat pump water heaters or sealed combustion furnaces and water heaters should be used
- A hot water-to-air coil in an air handling unit can be used to replace the gas furnace/heat exchanger. The coil can be connected to a sealed combustion (or power vented) water heater located within the conditioned space.
- Ductwork is not located in exterior walls or in the vented attic

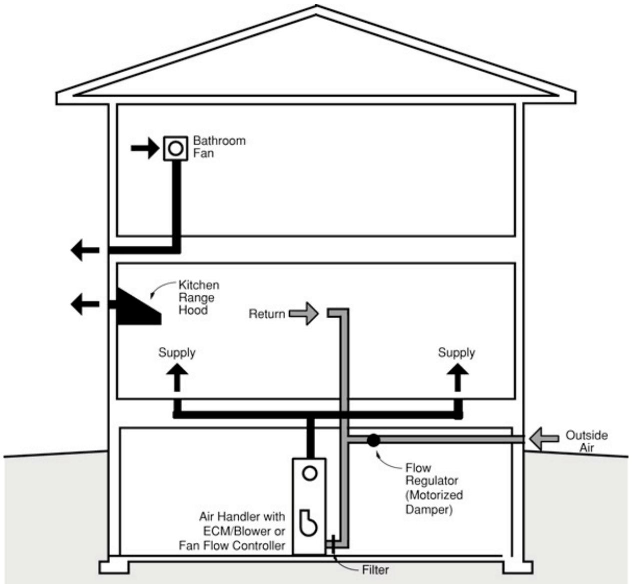
Vented and Conditioned Attic



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

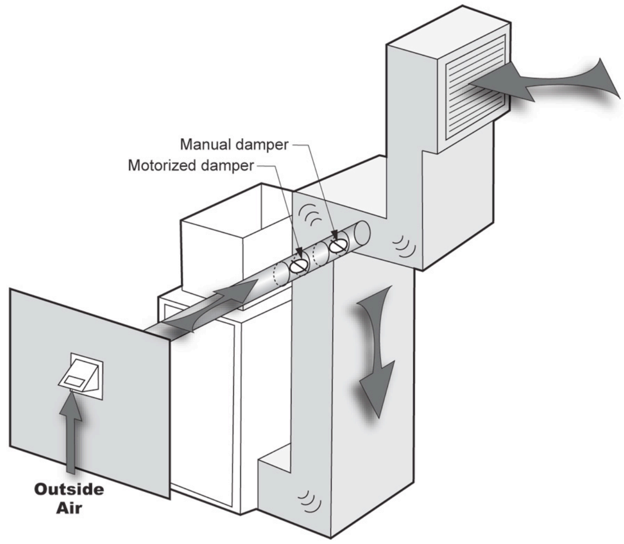
- The air handling unit is located in an unvented, conditioned attic; the attic insulation is located at or above the roof deck
- Low efficiency appliances that are prone to spillage or backdrafting are not recommended in this type of application; heat pumps, heat pump water heaters or sealed combustion furnaces and water heaters should be used
- A hot water-to-air in an air handling unit can be used to replace the gas furnace/heat exchanger. The coil can be connected to a sealed combustion (or power vented) water heater located within the conditioned space
- Ductwork is not located in exterior walls

Integrated Supply Ventilation System



- Air handler with ECM/blower runs continuously (or operated based on time of occupancy) pulling outside air into the return system
- A flow regulator (motorized damper) provides fixed outside air supply quantities independent of air handler blower speed
- House forced air duct system provides circulation and tempering
- Point source exhaust is provided by individual bathroom fans and a kitchen range hood
- In supply ventilation systems, and with heat recovery ventilation, pre-filtration is recommended as debris can affect duct and fan performance reducing air supply
- Kitchen range hood provides point source exhaust as needed
- Outside air duct should be insulated and positioned so that there is a fall/slope toward the outside to control any potential interior condensation. Avoid using long lengths of flex duct that may have a dip that could create a reservoir for condensation
- Mixed return air temperatures (return air plus outside air) should not be allowed to drop below 50° Fahrenheit at the design temperature in order to control condensation of combustion gases on heat exchanger surfaces

Outdoor Air Duct Connected to the Return of the Air Handler



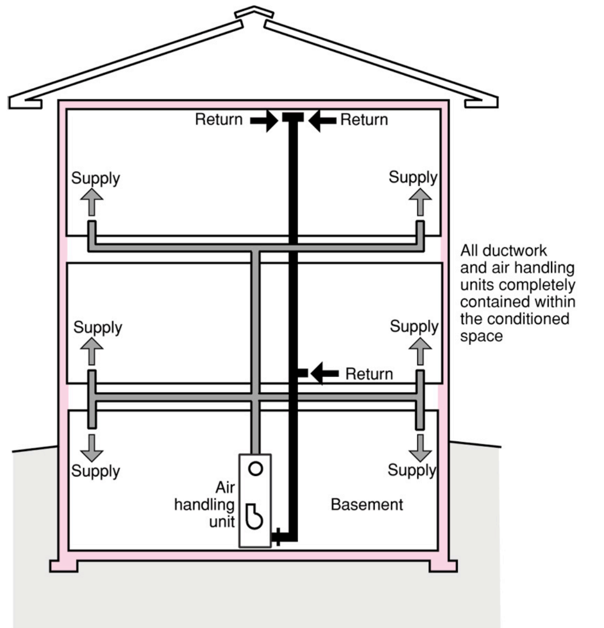
High Performance Housing — **Information Sheet 12**
for Greensburg, Kansas
Ductwork in Conditioned Space

The location of the duct system can have a significant impact on the overall performance of the system–both the utility use and the ability to provide comfort. The energy loss from the ducts for forced air heating and cooling systems can be significant, depending on the location of the ducts, and how well the ducts are sealed against air leakage. Though it is conceptually easy to imagine sealed duct systems, tight duct systems are unfortunately all too rare - duct leakage values of 20% of system flow are common. In many houses, the distribution duct work is located either in a vented crawlspace or in a vented attic – effectively outdoors. With the ducts located outside of the thermal envelope of the home, any leakage and conductive losses from the duct work is lost directly to the outside. Even worse, whenever air is leaking out or the ducts due to the system running, air is coming into the house to replace the lost air—resulting in forced air leakage whenever your furnace or air conditioner runs.

Moving the duct work and air handlers inside the thermal enclosure can be used to help prevent this energy loss to the exterior. Alternately, the thermal enclosure can be extended to include areas such as crawlspaces and attic as part of the conditioned space of the house.

In general, the placement of the mechanical equipment will depend on the design of the house. For houses with conditioned crawlspaces and basements, it is often logical to place the air handler or furnace in those locations. For slab on grade designs or elevated floors, available space can become a limitation. In these cases, unvented conditioned and semi-conditioned attics provide for a convenient location for the mechanical equipment and ducts. Otherwise, the equipment and / or ducts can be located in a dropped ceiling or in closets. Consideration for space requirements for the mechanical equipment should be made early in the design.

Vented and Unconditioned Attic



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

- The air handling unit is located in a conditioned basement
- Low efficiency gas appliances that are prone to spillage or backdrafting are not recommended in this type of application; heat pumps, heat pump water heaters or sealed combustion furnaces and water heaters should be used
- A hot water-to-air coil in an air handling unit can be used to replace the gas furnace/heat exchanger. The coil can be connected to a sealed combustion (or power vented) water heater located within the conditioned space.
- Ductwork is not located in exterior walls or in the vented attic

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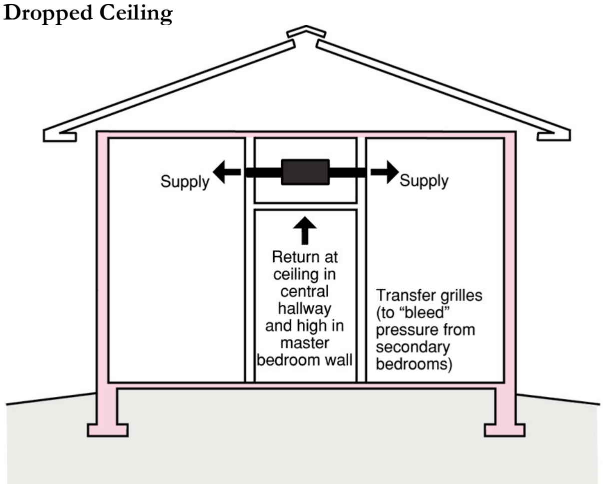
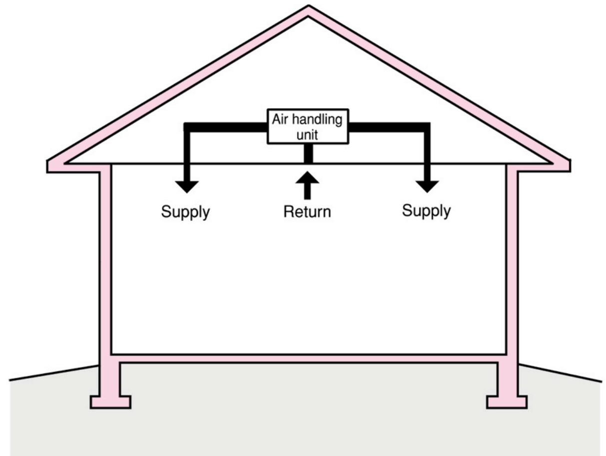
Vented and Unconditioned Attic with a Dropped Ceiling



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

- In this approach, exterior wall heights are typically increased to 9-feet or more leaving hallway ceiling heights at 8-feet
- The air handling unit is located in an interior closet and the supply and return ductwork are located in a dropped hallway
- Transfer grilles "bleed" pressure from secondary bedrooms
- Ductwork does not have to extend to building perimeters when thermally efficient windows (low-E, spectrally selective) and thermally efficient (well-insulated 2x6 frome walls with 2" of insulating sheathing) building enclosure construction is used; throw-type registers should be selected
- Low efficiency gas appliances that are prone to spillage or backdrafting are not recommended in this type of application; heat pumps, heat pump water heaters or sealed combustion furnaces and water heaters should be used
- A hot water-to-air coil in an air handling unit can be used to replace the gas furnace/heat exchanger. The coil can be connected to a sealed combustion (or pwer vented) water heater located within the conditioned space.
- Ductwork is not located in exterior walls or in the vented attic

Vented and Conditioned Attic



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

- The air handling unit is located in an unvented, conditioned attic; the attic insulation is located at or above the roof deck
- Low efficiency appliances that are prone to spillage or backdrafting are not recommended in this type of application; heat pumps, heat pump water heaters or sealed combustion furnaces and water heaters should be used
- A hot water-to-air in an air handling unit can be used to replace the gas furnace/heat exchanger. The coil can be connected to a sealed combustion (or power vented) water heater located within the conditioned space
- Ductwork is not located in exterior walls

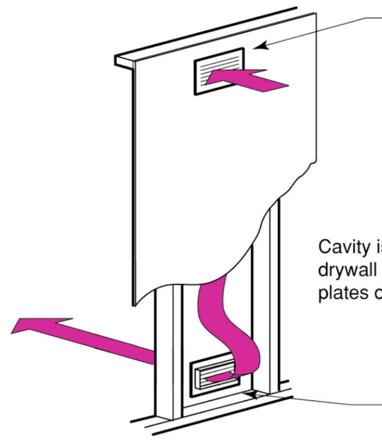
High Performance Housing — **Information Sheet 13**
for Greensburg, Kansas
Transfer Ducts and Grilles

The ductwork systems in these houses are designed to supply air to the individual rooms, and to have the air return to a central return grille. The Manual J (i.e. heating and cooling load) calculations typically yield the airflow requirements to the various rooms to meet those design loads. These airflow volumes are then used to size and lay out the ducts.

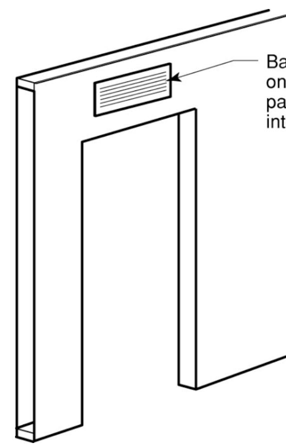
With any distribution system, there must be a return path for the energy distributing fluid. In the case of an air-based duct system, there is a central return that is open to the primary living space, with transfer means from bedrooms to the main space. The return path from the bedrooms needs to allow sufficient return flow to prevent room pressurization and prevent supply flow from being "choked" off. While undercutting doors can create part of the return air path, wall transfer grilles or jump ducts should be installed to prevent the return problems stated above.

All supply registers should have clear access to a return grille in order to prevent the pressurization of bedrooms and the depressurization of common areas. Bedrooms should either have a direct-ducted return or a transfer grille. Undercutting of bedroom doors rarely works and should not be relied upon to relieve bedroom pressurization. A central "hard" ducted return that is airtight and coupled with transfer grilles to relieve bedroom pressurization significantly outperforms a traditional return system, which has leaky ducted returns in every room, stud bays used as return ducts, and panned floor joists.

Transfer Grille

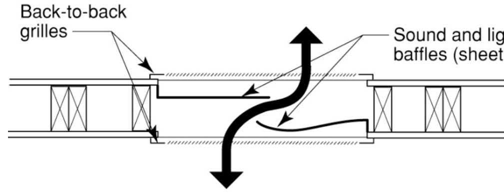


Transfer Grille—Over Door Opening



- Relieves pressure differences between spaces
- Interior baffles control sound and light transfer
- Door undercut of 1" minimum still required

Transfer Grille—Section



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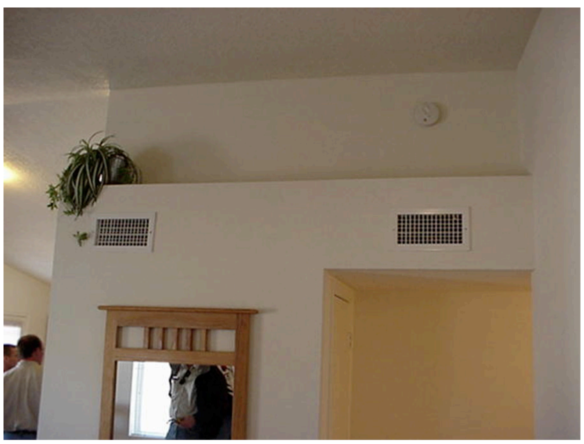
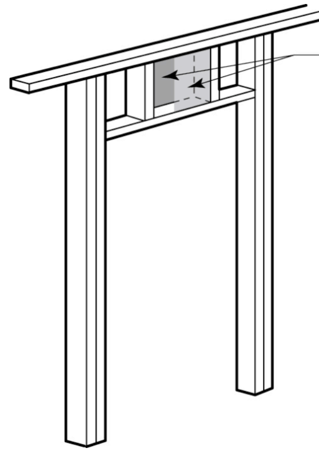
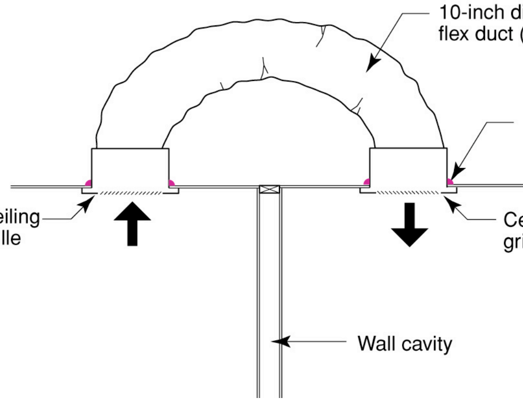


Transfer Grille—Construction



Jump Ducts



High Performance Housing — **Information Sheet 15** *for Greensburg, Kansas*

Last updated on March 3, 2008

Duct Sealing

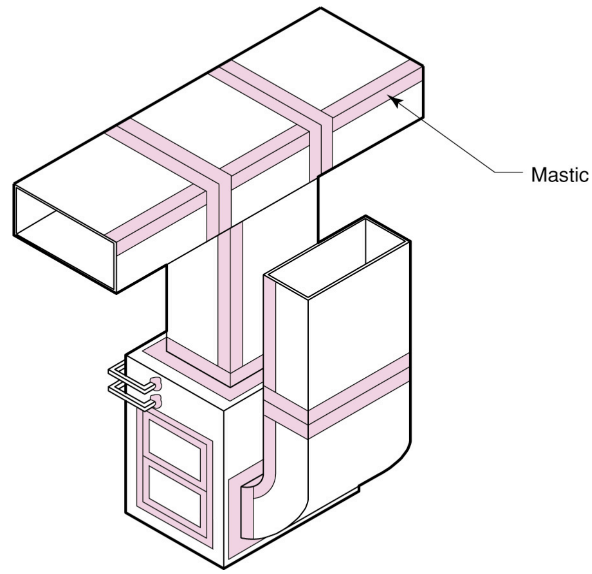
Ductwork, furnaces and air handlers should be sealed against air leakage. The only place air should be able to leave the supply duct system and the furnace or air handling unit is at the supply registers. The only place air should be able to enter the return duct system and the furnace or air handling unit is at the return grilles. A forced air system should be able to be pressure tested the way a plumber pressure tests a plumbing system for leaks. Builders don't accept leaky plumbing systems, so they should not accept leaky duct systems.

Supply systems should be sealed with mastic in order to be airtight. All openings (except supply registers), penetrations, holes and cracks should be sealed with mastic or fiberglass mesh and mastic. Tape, especially duct tape, does not work and should not be used. Sealing of the supply system includes sealing the supply plenum, its attachment to the air handler or furnace, and the air handler or furnace itself. Joints, seams and openings on the air handler, furnace or ductwork near the air handler or furnace should be sealed with both fiberglass mesh and mastic due to greater local vibration and flexure.

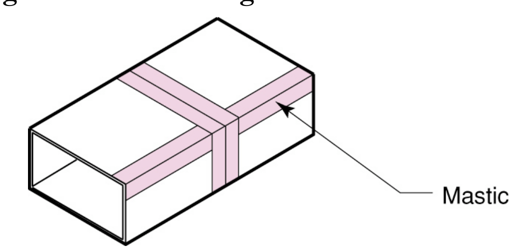
Return systems should be "hard" ducted and sealed with mastic in order to be airtight. Building cavities should never be used as return ducts. Stud bays or cavities should not be used for returns. Panned floor joists should not be used. Panning floor joists and using stud cavities as returns leads to leaky returns and the creation of negative pressure fields within interstitial spaces. Carpet dustmarking at baseboards, odor problems, mold problems and pollutant transport problems typically occur when building cavities are used as return ducts.

The longitudinal seams and transverse joints in sheet metal ducts should be sealed. The inner liner or insulated plastic flex duct should be sealed where flex ducts are connected to other ducts, plenums, junction boxes and boots/registers.

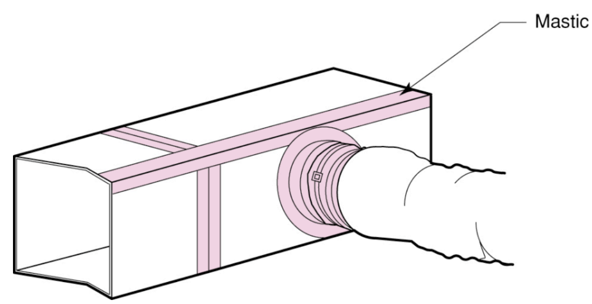
Air Handler Air Sealing



Rigid Duct Air Sealing



Flex Take-off from Rigid Air Sealing



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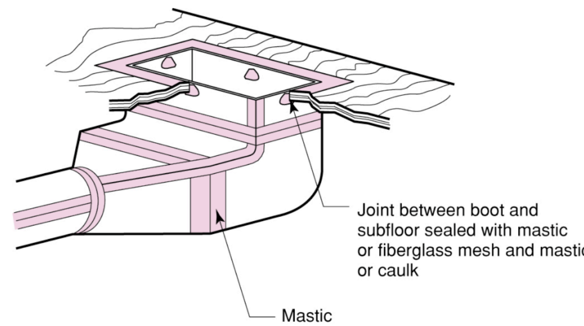
In flex duct installation, the outer liner and insulation should be pulled back and the inner liner attached to the collar with a tie. Fiberglass mesh tape (fabric) should be installed over the inner liner and collar such that at least 1 inch of fiberglass mesh tape covers the exposed collar. Mastic is then applied over the fiberglass mesh tape. The insulation and the outer liner is then pulled back over the connection and sealed with a second tie. When flex ducts are used, care must be taken to prevent restricting air flow by "pinching" ducts.

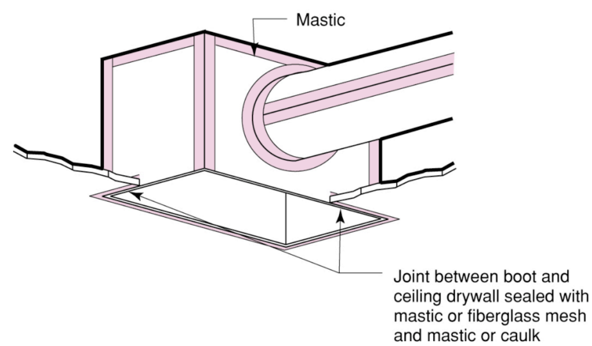
Connections between grilles, registers and ducts at ceilings, floors or knee walls typically leak where the boot does not seal tightly to the grille or gypsum board. Air from the attic, basement, or crawlspace can leak in or out where the ducts connect to the boot.

If the gap between boots and gypsum board opening or subfloor openings is kept to less than 3/8-inch, a bead of sealant or mastic may be used to seal the gap. Where gaps are larger than 3/8-inch, fabric and mastic should both be used. The optimum approach is to keep the gaps to less than 3/8-inch and use a bead of sealant. This requires careful coordination with the drywall contractor to make sure that the rough openings for the boots are cut no more than 3/8-inch bigger than the actual boot size on all sides.

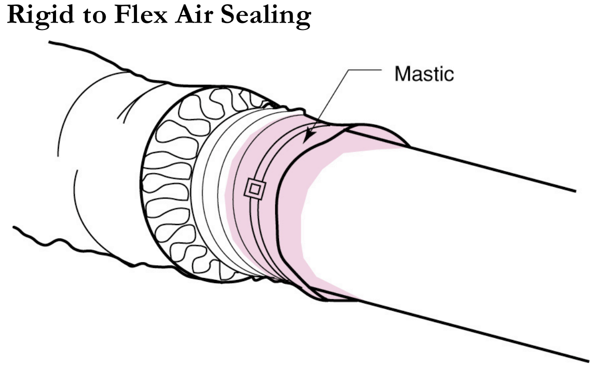
Floor Boot Air Sealing



Ceiling Boot Air Sealing



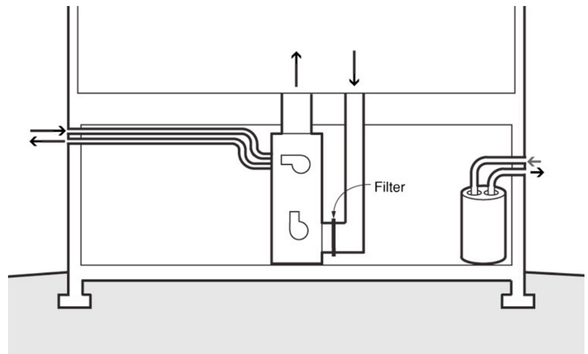
Rigid to Flex Air Sealing



High Performance Housing — **Information Sheet 17**
for Greensburg, Kansas
Sealed Combustion Water Heaters

In order to ensure good indoor air quality, all combustion appliances are recommended to be sealed combustion units, as opposed to naturally aspirated units. These systems are completely decoupled from the interior environment through the use of dedicated outdoor air intake and exhaust ducts connected directly to the unit. This change completely disconnects the combustion process from the interior environment, and eliminates concerns of back-drafting of the unit. In addition, it allows the elimination of the usual make-up air ducts. These make-up air ducts (required for naturally aspirated units) are a source of uncontrolled air leakage through the building enclosure, and therefore increase energy use. Finally, the sealed combustion appliances tend to be more efficient than the naturally aspirated units.

Spillage or backdrafting of combustion appliances is unacceptable. Only sealed combustion, direct vented, power vented or induced draft combustion appliances should be installed inside conditioned spaces for space conditioning or for domestic hot water. Traditional gas water heaters with draft hoods are prone to spillage and backdrafting. They should be avoided. Gas ovens, gas stoves or gas cooktops should only be installed with an exhaust range hood directly vented to the exterior. Wood-burning fireplaces or gas-burning fireplaces should be supplied with glass doors and exterior combustion air ducted to the firebox. Wood stoves should have a direct ducted supply of combustion air. Unvented (ventless) gas fireplaces or gas space heaters should never be installed. Sealed combustion direct vent gas fireplaces are an acceptable alternative. Portable kerosene heaters should never be used indoors.



- Water heater combustion air supplied directly to water heater from exterior via duct; products of combustion exhausted directly to exterior also via duct
- Furnace flue gases exhausted to the exterior using a fan; combustion air supplied directly to furnace from exterior via duct

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High Performance Housing — **FAQ**
2006 IRC
Basement Insulation

Q: *What are the code recommendations for basement insulation? Does the building code allow me to leave my insulation exposed in the basement?*

A: For climate zones 4 through 8, the 2006 IRC requires that insulation be installed on the basement walls if the basement is conditioned, or if the basement is not conditioned insulation must be installed on the basement walls or in the floor separating the basement from the conditioned space above (*Section N1102.2.6 Basement Walls*).

The basement walls need to be insulated to a minimum value of R-10 for continuous insulation (such as foam plastic insulation) or R-13 for framing cavity insulation based on the component requirements of *Table N1102.1 Insulation and fenestration requirements by component*.

It is often recommended to insulate the basement walls with foam plastic insulation as the foam plastic insulations are not susceptible to deterioration when in contact with moisture (as can often be present in concrete basement walls). When using foam plastic insulation, the majority of products require a thermal barrier, usually ½" gypsum to be installed over the insulation (*Section R314.4 Thermal Barrier*) as a fire safety requirement. Certain foam plastic insulations such as DOW Thermax (*ICC-ES Legacy Report NER 681*) are rated to be left exposed on the interior of basement walls and do not need to be covered with a thermal barrier.

Applicable Code Sections:

2006 International Residential Code for One- and Two-Family Dwellings

- R314.3 Surface burning characteristics
- R314.4 Thermal barrier
- N1102 Building Thermal Envelope
- Table N1102.1 Insulation and fenestration requirements by component
- Table N1102.1.2 Equivalent U-factors
- N1102.2.6 Basement Walls

Additional References

- DOW Thermax ICC-ES Legacy Report NER 681

High Performance Housing — **FAQ**
2006 IRC
Wall Bracing Requirements for Insulating Sheathing

Q: *Can I install insulation board, in lieu of plywood, on the outside of an exterior wall?*

A: For some portion of, or for the entire exterior wall, the answer can be yes, depending on the design. The code provides options for houses that are in wind zones less than 110 mph.

Braced wall panels can be used instead of completely covering the entire building with plywood or OSB. While many types of braced wall panels are acceptable, the most common type of braced wall panels are: 1. A 4 foot wide sheet of plywood or OSB for outside walls and 2. Gypsum installed on interior walls. The various types of braced wall panels are described in *Section R602.10.3 Braced wall panel construction methods*. Standard braced wall panels need to a full 4 foot width with no cut outs from doors or window opening. Narrower panels can be used if the requirements of *Section R602.10.6 Alternate braced wall panels* are met.

A braced wall line and is made up of multiple braced wall panels on a wall. The number and location of the braced wall panels on a braced wall line depends on the wind speed, size and shape of the house, and number of stories. At minimum, braced wall panels are required at the corners and every 25 feet along the braced wall line; however the number may be increased depending on the shape and size of the house. This information can be found in *Table R602.10.1 Wall bracing*. This amount may need to be adjusted based on the weight of the roof assembly. The adjustment factors can be found in *Table R301.2.2.2.1 Wall bracing adjustment factors by roof covering dead load*.

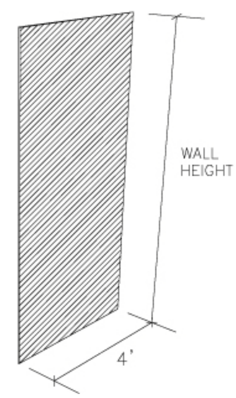

Figure 1: Braced wall panel

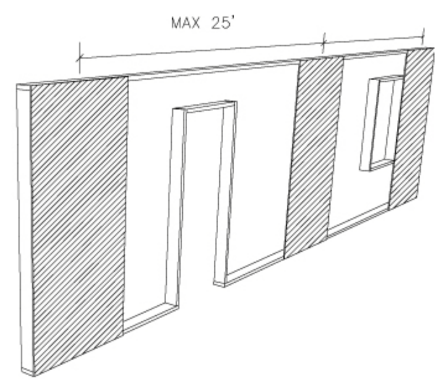

Figure 2: Braced wall line

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Every house has multiple braced wall lines running in parallel directions. A braced wall line is commonly required every 35 feet; however there are some exceptions to this rule. Keep in mind that the braced wall lines must run in both directions on a house (front to back and side to side). The number and spacing of braced wall lines is given in *Section R602.10.1 Braced wall lines*.

Dwellings in wind zones greater than 110 mph are not covered under this section of the International Residential Code. In cases where the window zone is greater than 110 mph, the design and construction of the structural elements must be in accordance with accepted engineering practice (Section *R602.10.10 Design of structural elements*).

Applicable Code Sections:

2006 International Residential Code for One- and Two-Family Dwellings

- R301.2.2.2.1 Weight of materials
- Table R301.2.2.2.1 Wall bracing adjustment factors by roof covering dead load
- R602.3 Design and construction
- R602.10 Wall bracing
- R602.10.1 Braced wall lines
- R602.10.3 Braced wall panel construction methods
- R602.10.10 Design of structural elements

Available Resources:

- WFCM 110 mph Guide to Wood Construction in High Wind Areas
- WFCM section 3.4.4.2 Exterior Shear Walls

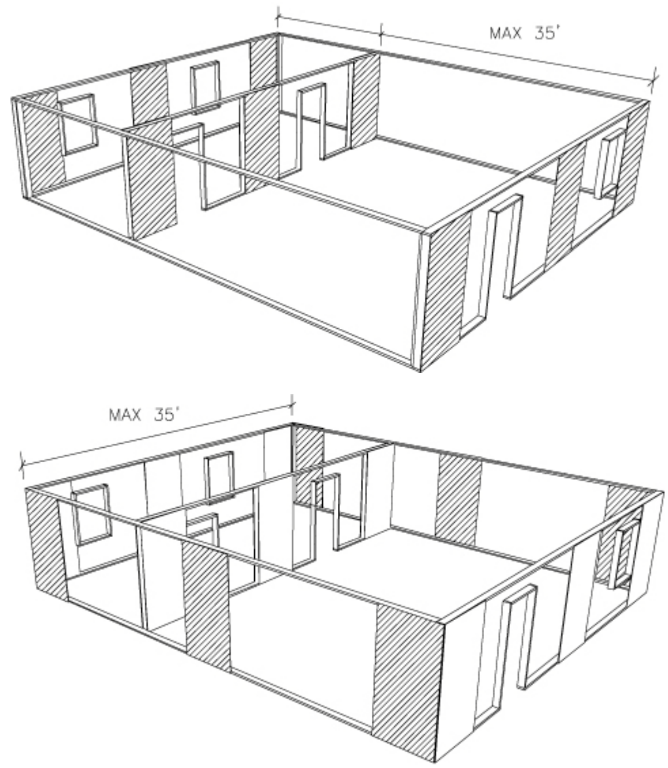

Figure 3: Braced wall lines spaced at 35 feet offsets in both directions

High Performance Housing — **FAQ**

2006 IRC

Insulating Sheathing Vapor Retarder Requirements

Q: *If insulation boards are installed on the outside of an exterior wall can the vapor retarder on the inside be removed?*

A: Yes, in certain cases. The addition of insulation boards on the exterior of the assembly helps reduce the potential for condensation occurring in the wall assembly. If enough insulation is added to the outside, then a vapor retarder on the inside is not necessary. Also, it is good practice to allow a wall assembly to be able to dry to at least one side, and since many insulation boards can be classified as vapor retarders, removing the vapor retarder from the inside allows increased drying of the assembly to the inside and improves the performance of the wall. The code recognizes this and addresses it in *Section N1102.5 Moisture Control* under Exception 3, which allows for the vapor retarder to be removed "where other means to control condensation are provided." However this still requires some calculations to demonstrate that the potential for condensation is managed in the proposed design.

The current 2007 Supplement to the International Residential Code (IRC) has made some changes to the definition and use of vapor retarders. These changes provide some clarity on vapor retarders, and can be used as guidance.

So what actually is a "vapor retarder"? The current 2006 IRC describes a vapor retarder as a material that has a permeance rating of 1.0 perms or less (*Section R202 Vapor retarder*). This seems simple enough, but there is in reality a large variation in performance between a product with a 1.0 perm rating and a product with a 0.1 perm rating. To address this, the International Code Council (ICC) added a new definition to Chapter 2 of the 2007 Supplement to the IRC for Vapor retarder class. The 2007 Supplement to the IRC currently defines vapor retarders under three classes:

Class I: 0.1 perm or less (Sheet polyethylene, non-perforated aluminium foil)

Class II: 0.1 perm <= 1.0 perm (Kraft faced fiberglass batts)

Class III: 1.0 perm <= 10 perm (Latex or enamel paint)

With the new definition for vapor retarder classes, new code language concerning the use for the new classes was also included. Class I and Class II vapor are needed to be installed on the warm in winter side of the insulation in Climate Zones 5, 6, 7, 8 and Marine 4 (*Section N1102.5 Vapor retarders*); however, Class III vapor retarders can now be used instead of Class I or II vapor retarders if the conditions of *Table 402.5.1 Class III vapor retarders* are met. In this table, provisions for using insulation boards are listed for various climate zones.

Applicable Code Sections:

2006 International Residential Code for One and Two-Family Dwellings

- R202 Vapor Retarder
- N1102.5 Moisture Control

2007 Supplement to the 2006 International Residential Code for One and Two-Family Dwellings

- R202 Vapor retarder Class
- N1102.5 Vapor retarders
- N1102.5.1 Class III vapor retarders
- N1102.5.2 Material vapor retarder class

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High Performance Housing — **FAQ**
2006 IRC
Cladding Attachment over Insulating Sheathing

Q: *How do I attach my siding, if I don't use wood sheathing? Does the code allow for attachment back to studs at 24" centers?*

A: The Code provides specific prescriptive guidance on cladding attachment and allows you to attach cladding at 24" centers.

In the 2006 International Residential Code (IRC) cladding attachment requirements are covered in *Section R703 Exterior covering* with the majority of the requirements summarized in *Table R703.4 Weather-resistant siding attachment and minimum thickness*.

When sheathings other than wood or wood structural panels are used (such as foam plastic insulating sheathing), the code requires that the cladding be fastened back to the studs. The stud spacing is not specifically stated in *Table 5703.4 Weather-resistant siding attachment and minimum thickness* and therefore other sections of the code must be referenced for acceptability of stud spacing. This information is found in Section *R602.3.1 Stud size, height and spacing* in conjunction with *Table R602.3(5) Size, height and spacing of wood studs* listing that studs spaced at 24" centers are acceptable for certain walls.

Depending on the type of cladding, thickness of cladding, and type and thickness of sheathing different fasteners may be required. The penetration depth of the fastener into the stud is the basic requirement. For most claddings the fastener length is specified since the cladding and sheathing thickness is known, a minimum penetration depth is assumed. Where the sheathing thickness is variable (such as with foam plastic insulating sheathing), the fastener size needs to take into account the siding thickness and thickness of sheathing and still provide a minimum of 1" to 1.5" penetration (depending on the cladding type) into the stud.

In many cases furring strips are included in the design of the wall cladding to create a ventilation and drainage space behind the cladding. In this configuration it is often preferable to fasten the cladding to the furring strips instead of back to the studs. Unfortunately the code does not specifically cover this cladding system configuration so engineering may be required to design the cladding attachment to meet the cladding wind load requirements for the area.

Applicable Code Sections:

2006 International Residential Code for One- and Two-Family Dwellings

- R602.3.1 Stud size, height and spacing
- Table R602.3.1 Size, height and spacing of wood studs
- R703 Exterior covering
- Table R703.4 Weather-resistant siding attachment and minimum thickness

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For more information about the Greensburg, Kansas project go to **Greensburg.buildingscience.com**

High Performance Housing — **FAQ**
2006 IRC
Conditioned Attics

Q: *I want to make my attic into living space by moving the insulation to the underside of the roof deck between the joists? How do I meet the roof venting requirements of the building code if I do this?*

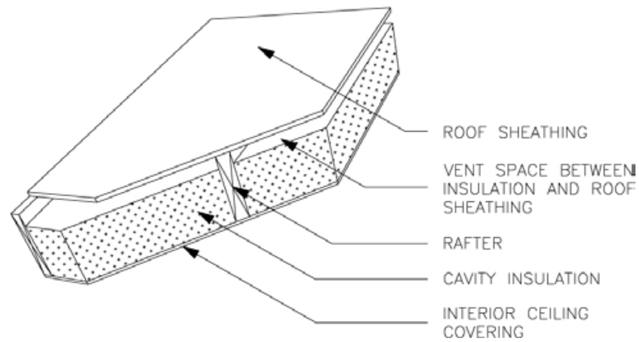

Figure 1: Vented cathedral roof assembly

A: There are two ways that this can be accomplished. You can insulate the rafter space provided that you leave a ventilation space between the top of the insulation (typically fiberglass batts or blown cellulose) and the underside of the roof sheathing (*Section R806.1 Ventilation required*). The minimum net free area of the ventilation space is described in *Section R806.2 Minimum area* and *Section R806.3 Vent and insulation clearance*.

Alternately, an unvented attic assembly can be created based on the requirements of *Section R806.4 Conditioned attic assemblies*. In essence two methods are available, install air impermeable expanding spray foam insulation to the underside of the roof deck or install rigid board foam plastic insulation above the roof deck. The language and various requirements that must be met are somewhat complicated to follow and require calculations to determine the minimum amount of insulation required to "*maintain the monthly average temperature of the condensing surface above 45F (7C)*".

To help clarify, the International Code Council (ICC) introduced new language into *Section R806.4 Unvented attic assemblies* of the 2007 Supplement to the International Residential Code (IRC). This section includes *Table R806.4 Insulation for condensation control*, which provides prescriptive requirements for minimum rigid board or air impermeable insulation R-values based on climate zone in order to manage the condensation potential in the assembly.

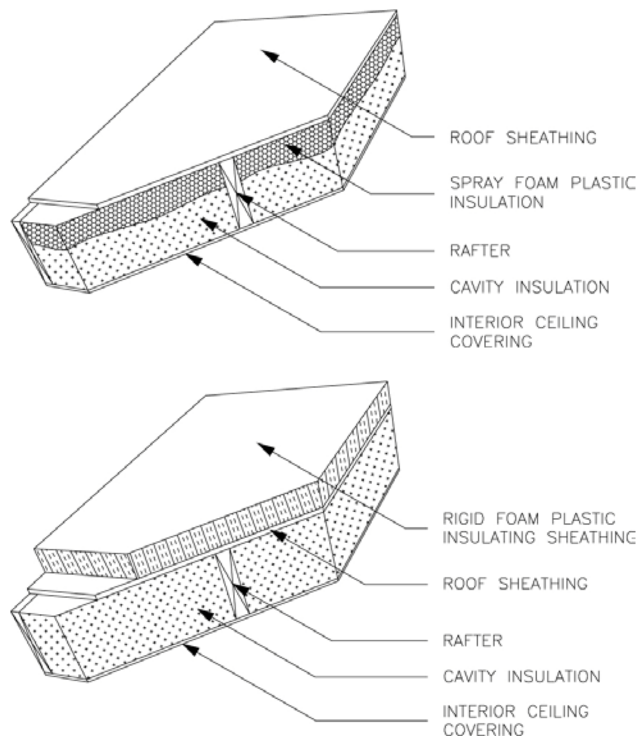

Figure 2: Unvented roof assemblies

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Applicable Code Sections:

2006 International residential Code for One- and Two-Family Dwellings

- R806.1 Ventilation required
- R806.2 Minimum area
- R806.3 Vent and insulation clearance
- R806.4 Conditioned attic assemblies

2007 Supplement to the International Residential Code

- R806.4 Unvented attic assemblies
- Table R806.4 Insulation for condensation control

B.5 Building for Energy Efficiency – Part 1

Alex Lukachko
Building Science Consulting

Building for Energy Efficiency – Part 1

How to Design the Enclosure for a Home that Uses Less Energy at Little or No Additional Cost

Alex Lukachko
Building Science Consulting LLC
www.buildingscience.com

Building America

The U.S. Department of Energy's Building America Program is reengineering the American home for energy efficiency and affordability. Building America works with the residential building industry to develop and implement innovative building processes and technologies – innovations that save builders and homeowners millions of dollars in construction and energy costs. This industry-led, cost-shared partnership program uses a systems engineering approach to reduce energy use, utility bills, construction time, and construction waste.

For more information, visit our website at:
www.buildingamerica.gov

Objectives for this morning . . .

1. Help make decisions
2. Explain energy efficiency approach
3. Demonstrate business opportunities

Why build energy efficient homes?

Consumers:

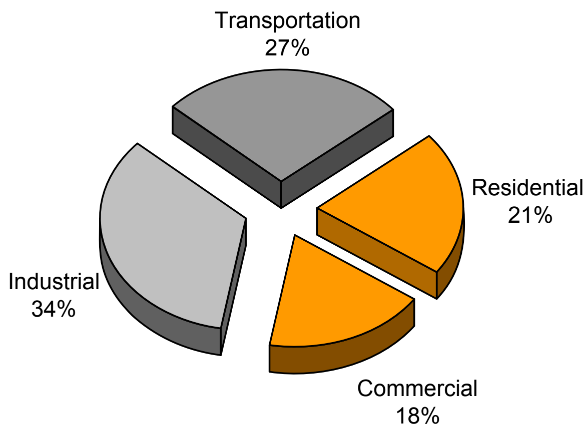
- Lower energy bills and maintenance costs
- More money for things other than energy
- Healthier, more comfortable, more durable homes

The nation:

- Wise use of resources through energy savings
- Greater energy security through the use of domestic resources
- A healthier environment through reduced emissions
- Increased use of onsite power and renewable energy systems

Assessing the Impact of US Buildings

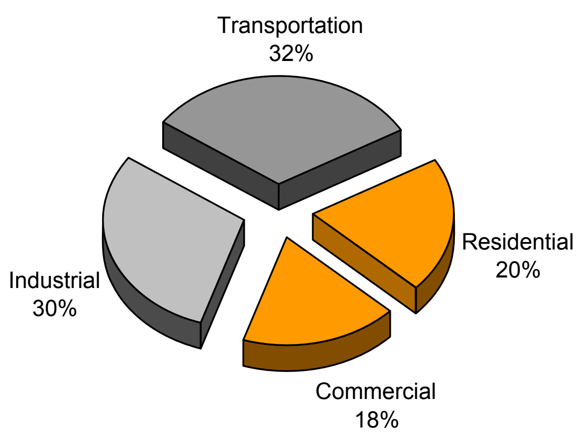
Total Energy Consumption by Sector, 2001



Source: EIA, Annual Energy Review, 2001 data - www.eia.doe.gov/emeu/aer

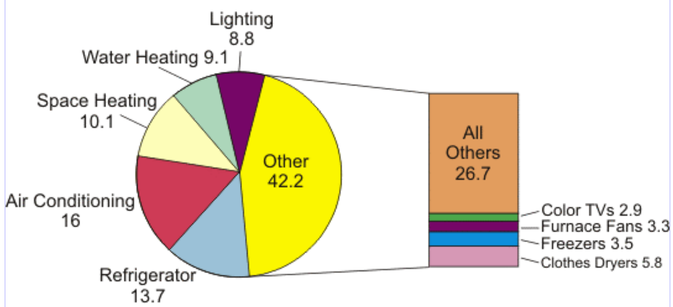
Contribution to Climate Change

Carbon Dioxide Emissions from Energy Consumption by Sector, 2001



Source: EIA, Annual Energy Review, 2001 data - www.eia.doe.gov/emeu/aer

Background – Energy Use in the Home



Source: Energy Information Administration, Form EIA-457A, B, C, E, and H of the 2001 Residential Energy Consumption Survey.

Overview of the Design approach

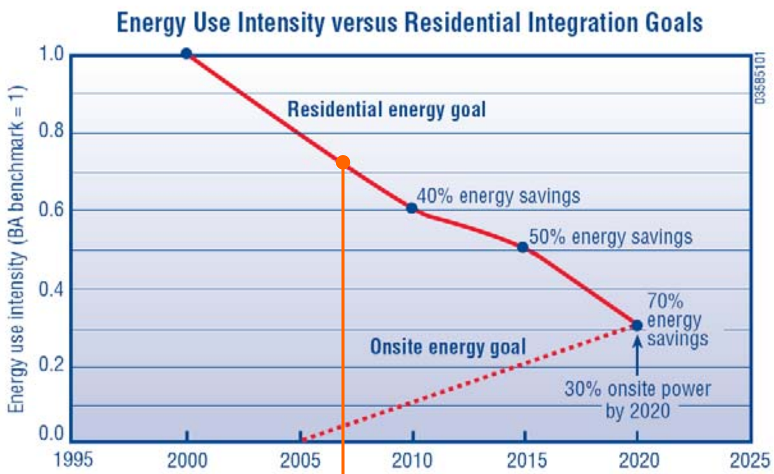
Our approach follows three general steps:

Step 1: Reduce Enclosure Energy Use

Step 2: Reduce Mechanical System Energy Use

Step 3: Add Site Generated Energy

Building America Research Goals



25,000 houses in 34 states

Systems Engineered for Zero Cost

Source: Building America. 1999. *Cost Saving System Trade-offs for Mixed Climates.* *U.S. Department of Energy*, Washington, D.C. www.buildingamerica.gov

Looking long-term . . .

MIXED-HUMID CLIMATE CASE STUDY HOUSE
Richmond, VA

STEP	DESCRIPTION OF STEP	Estimated Individual Cost of Change	Estimated Cumulative Cost of Change	TOTAL SOURCE ENERGY SAVINGS (heating, cooling, dhw, lighting, appliances, plug loads) over BA Benchmark	Incremental	Annual Energy Cost	Simple Payback (yr)	Incremental Payback (yr)
0	Benchmark	n/a	n/a	n/a	n/a	$1,288	n/a	n/a
1	Benchmark + Enclosure Upgrades	$400	$400	6.0%	6.0%	$1,210	5	5
2	Above + Mechanical Upgrades	$1,000	$1,400	21.9%	16.0%	$1,000	5	5
3	Above + Lights & Appliances	$350	$1,750	27.4%	5.4%	$929	5	5
4a	3 + 17 EER, 4 COP GSHP	$6,000	$7,750	33.3%	6.0%	$851	18	77
4b	3 + 40 sq ft SHW	$3,700	$5,450	38.5%	11.1%	$765	10	23
4c	3 + 2kW PV	$10,000	$11,750	41.7%	14.3%	$758	22	58
5	All Strategies	$19,700	$21,450	58.8%	31.4%	$516	28	48

- **Balance initial investment with long-term savings**
- **Add technology in a cost-effective manner**

Overview of the Design approach

Top ten elements in the design of high performance homes:

1. Design for comfort with as little added energy as possible
2. Built tight
3. Ventilate
4. Use more insulation
5. Provide for durability by controlling moisture
6. Design a roof that is sloped to the south
7. Use the most efficient equipment the project can afford
8. Use efficient lighting, appliances and match to occupant needs
9. Reduce energy use 40-70% before adding onsite energy generation
10. Commission mechanical and onsite energy systems

Overview of the Design approach

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1. Design for comfort with as little added energy as possible

Start with the building itself

1. **Siting** (choice of building site or position on it)
   - exposure to wind and rain
   - micro-climate: trees for shading, wind-blocks
2. **Orientation**
   - windows south, "service" rooms north
   - positioning and size of windows and doors
3. **Building form**
   - external features: overhangs, breezeways, porches
   - building size and shape

- **At each step there are opportunities to reduce the energy that the building will use**
- **These changes decisions can't be made later**

Breezeways and Porches

Overhangs

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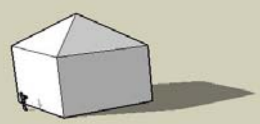
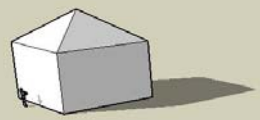
House size and form – Unvented Roof



Plan 'A'
30' x 30'
2 Stories
8:12 roof

18

House size and form – Unvented Roof

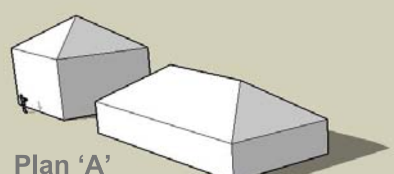


Plan 'A'
30' x 30'
2 Stories
8:12 roof

Floor Area 1800 sq ft
Surface Area **4142** sq ft

19

House size and form – Unvented Roof



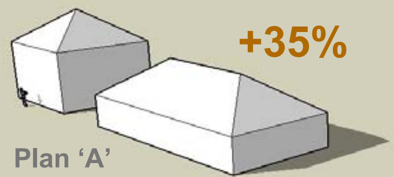
Plan 'A'
30' x 30'
2 Stories
8:12 roof

Plan 'B'
30' x 60'
1 Story
8:12 roof

Floor Area 1800 sq ft
Surface Area **4142** sq ft

20

House size and form – Unvented Roof



+35%

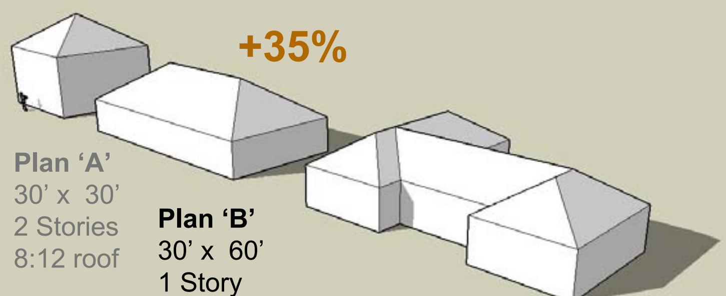
Plan 'A'
30' x 30'
2 Stories
8:12 roof

Plan 'B'
30' x 60'
1 Story
8:12 roof

	Plan 'A'	Plan 'B'
Floor Area	1800 sq ft	1800 sq ft
Surface Area	**4142** sq ft	**5583** sq ft

21

House size and form – Unvented Roof



+35%

Plan 'A'
30' x 30'
2 Stories
8:12 roof

Plan 'B'
30' x 60'
1 Story
8:12 roof

	Plan 'A'	Plan 'B'
Floor Area	1800 sq ft	1800 sq ft
Surface Area	**4142** sq ft	**5583** sq ft

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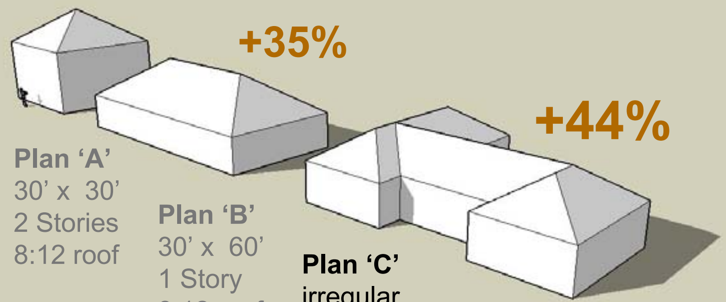
bsc

House size and form – Unvented Roof



Plan 'A'
30' x 30'
2 Stories
8:12 roof

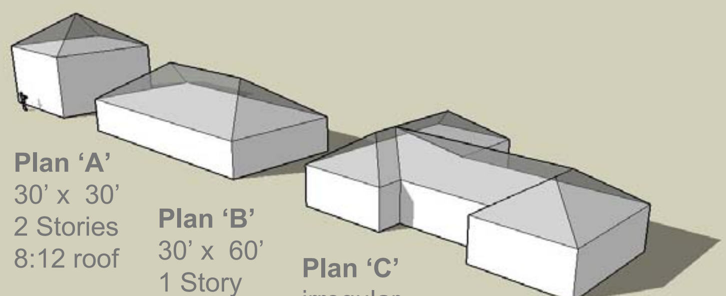
Plan 'B'
30' x 60'
1 Story
8:12 roof

Plan 'C'
irregular
1 Story
8:12 roof

	Plan 'A'	Plan 'B'	Plan 'C'
Floor Area	1800 sq ft	1800 sq ft	1800 sq ft
Surface Area	**4142** sq ft	**5583** sq ft	**5944** sq ft

bsc

House size and form – Vented Roof



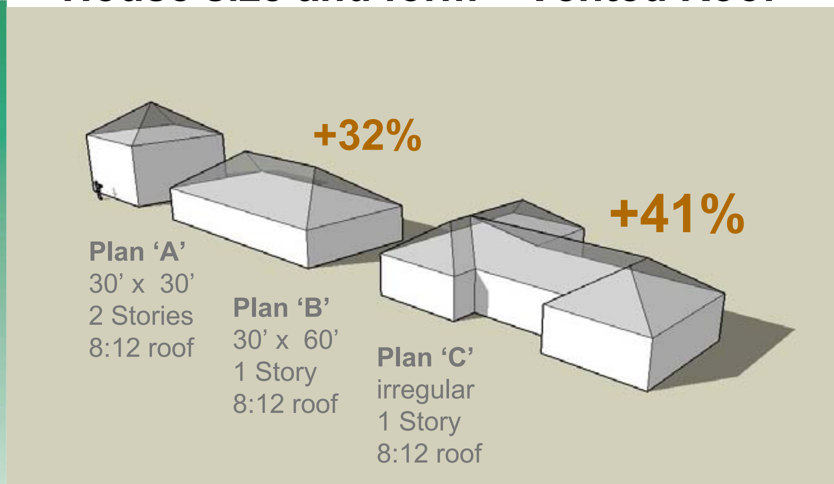
Plan 'A'
30' x 30'
2 Stories
8:12 roof

Plan 'B'
30' x 60'
1 Story
8:12 roof

Plan 'C'
irregular
1 Story
8:12 roof

	Plan 'A'	Plan 'B'	Plan 'C'
Floor Area	1800 sq ft	1800 sq ft	1800 sq ft
Surface Area	**3960** sq ft	**5220** sq ft	**5580** sq ft

House size and form – Vented Roof

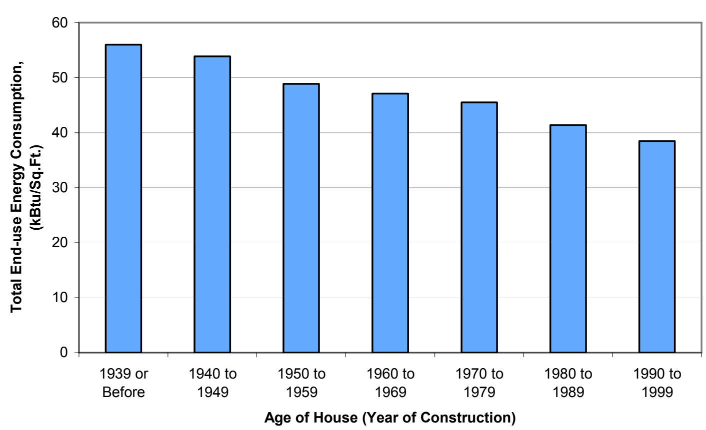


	Plan 'A'	Plan 'B'	Plan 'C'
Floor Area	1800 sq ft	1800 sq ft	1800 sq ft
Surface Area	**3960** sq ft	**5220** sq ft	**5580** sq ft
Volume	**16200** ft^3	**16200** ft^3	**16200** ft^3

25

Energy Efficient Construction is Catching on

Total End-Use Residential Energy Consumption in 2001 per Square Foot by Age of Construction



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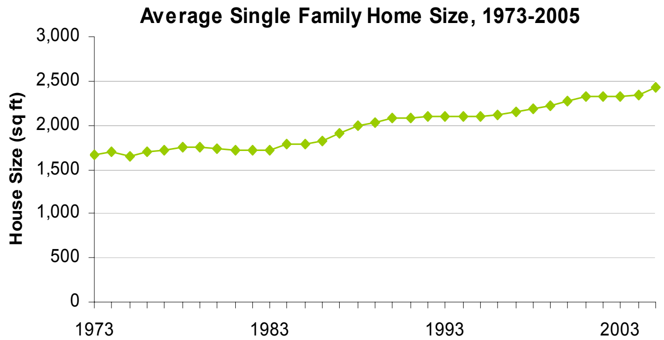
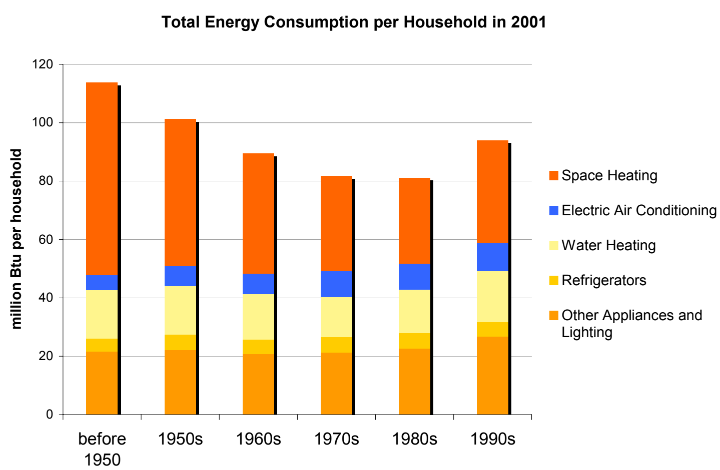
But size matters . . .

- Average House Size in **1940: ~1100 sq ft**[1]
- Average House Size in **1973: 1660 sq ft**[2]
- Average House Size in **2005: 2434 sq ft**



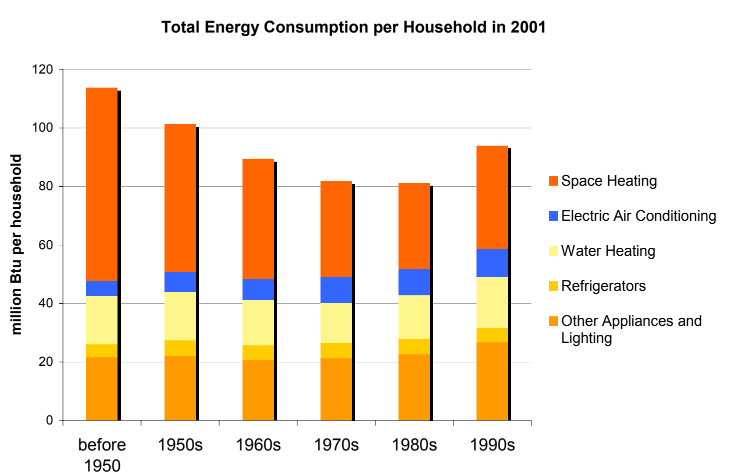
1. Wilson, Alex and Jessica Boehland "Small is Beautiful" *Journal of Industrial Ecology*, Vol 9, No 1-2. 2005
2. EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

Total Energy Use is on the Rise



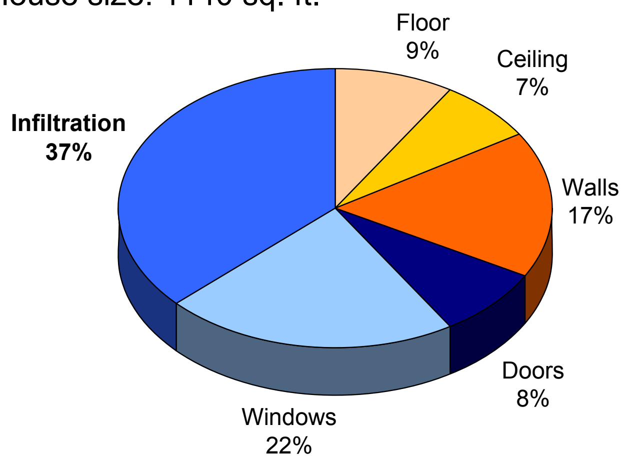
2. Build tight

Total Energy Use is on the Rise



How the heating loads break down

House size: 1140 sq. ft.



Heating is the largest of all energy use, and infiltration is the biggest contributor to the heating load

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Why airtight buildings?

Reasons to control airflow:

- Energy - Heat loss/gain
- Durability - Air leakage condensation
- Occupant health - Pollution and odors
- Occupant comfort - Drafts, noise

Do this using an "AIR BARRIER SYSTEM"

- Many materials are air impermeable, most systems are not

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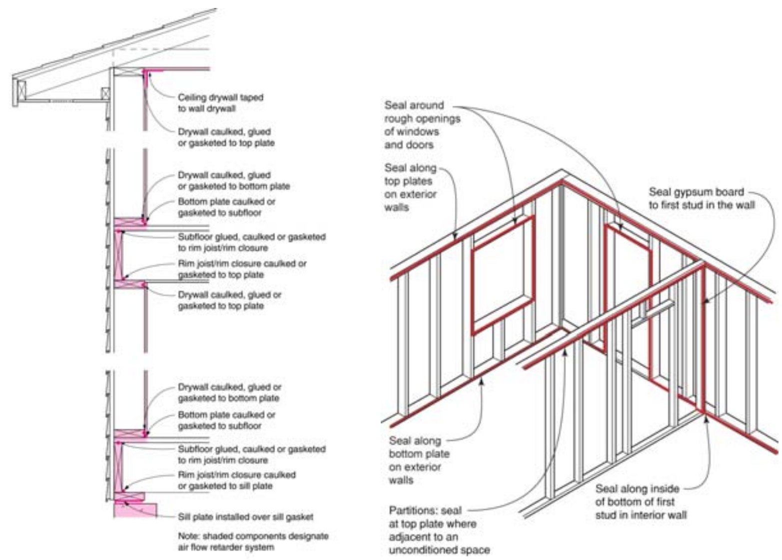
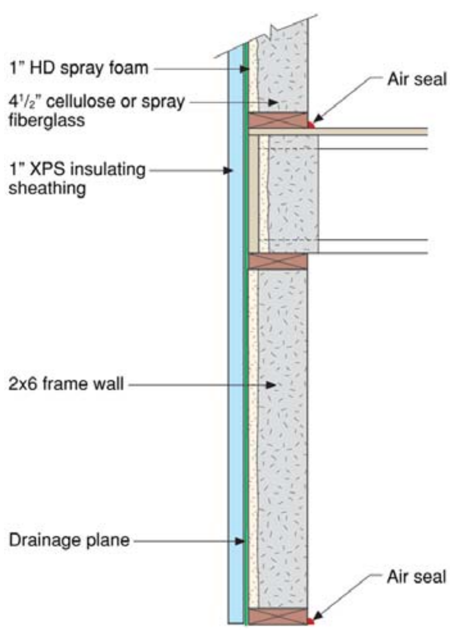
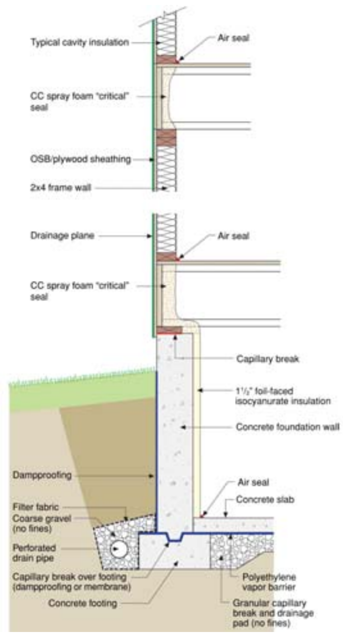


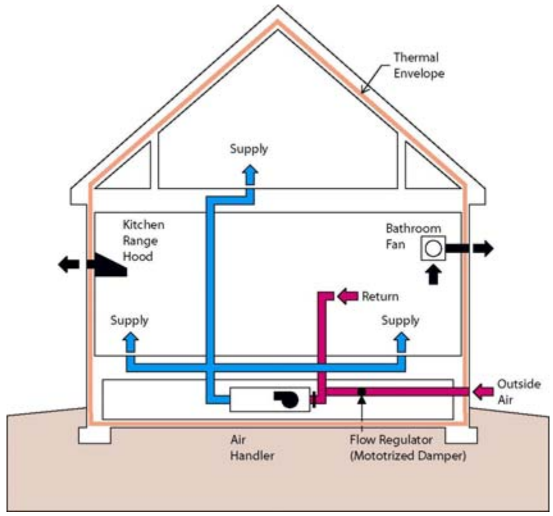
Interior Air Flow Retarder Using Drywall and Framing




Typical cavity insulation
Air seal
CC spray foam "critical" seal
OSB/plywood sheathing
2x4 frame wall
Drainage plane
Air seal
CC spray foam "critical" seal
Capillary break
1½" foil-faced isocyanurate insulation
Concrete foundation wall
Dampproofing
Air seal
Concrete slab
Filter fabric
Coarse gravel (no fines)
Perforated drain pipe
Capillary break over footing (dampproofing or membrane)
Concrete footing
Polyethylene vapor barrier
Granular capillary break and drainage pad (no fines)

3. Ventilate

Airtight Enclosure and Mechanical System



Where should you put the holes?

Outside Air Intake

Direct vented to outside

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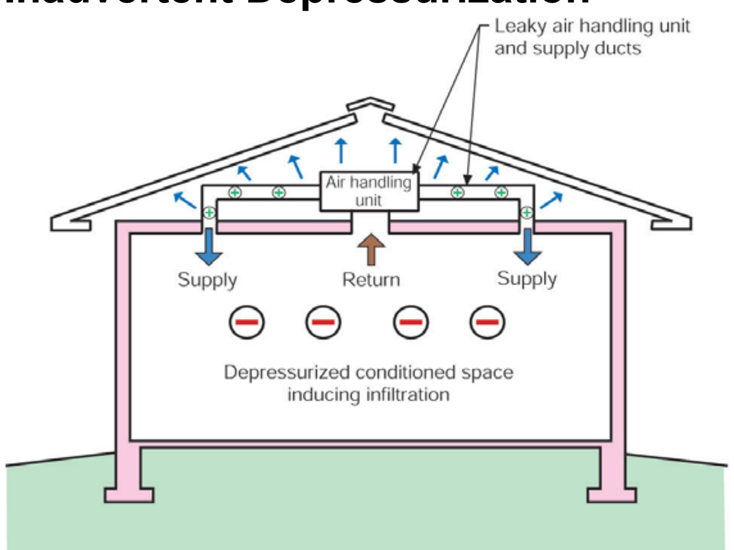
Consulting

Inadvertent Depressurization



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

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Tight Ductwork and Sealed Combustion

43

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4. Use more insulation

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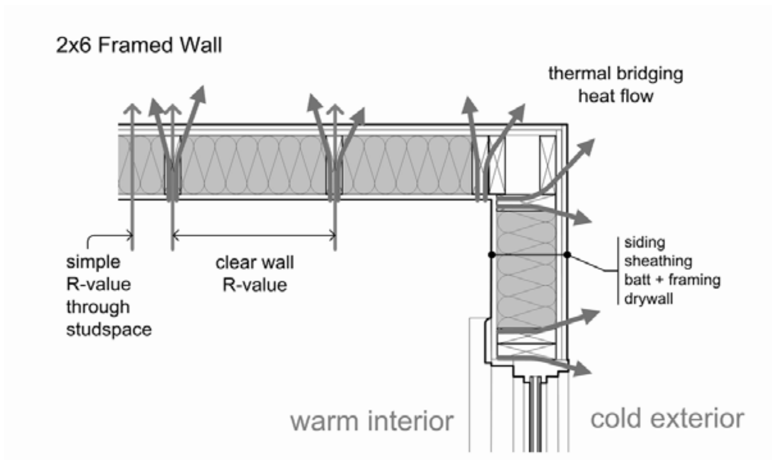
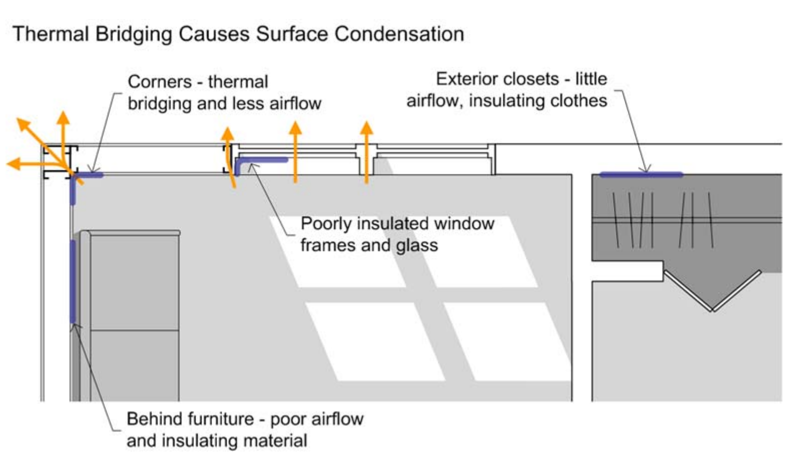
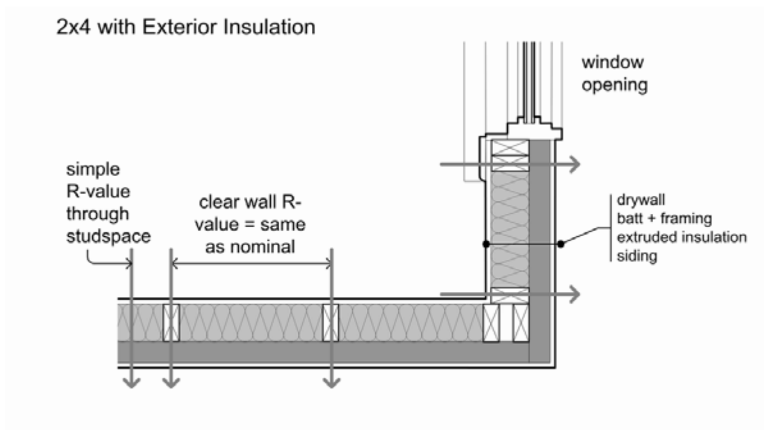
It’s not just how much you use . . .



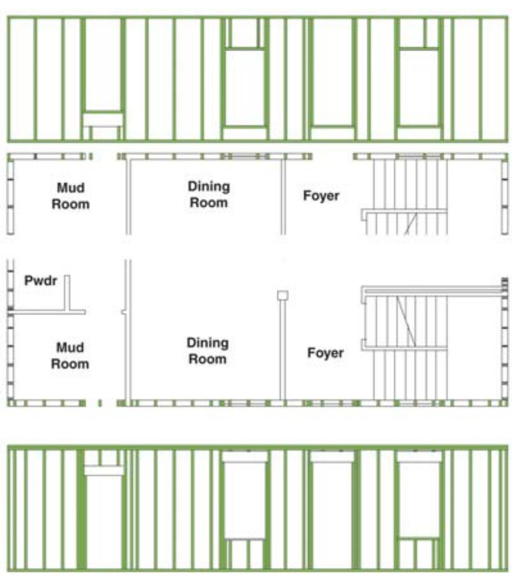
Surface temperature and condensation



Eliminating thermal bridging



Advanced Wall Framing



Wall 1 (2x6 24"o.c.)

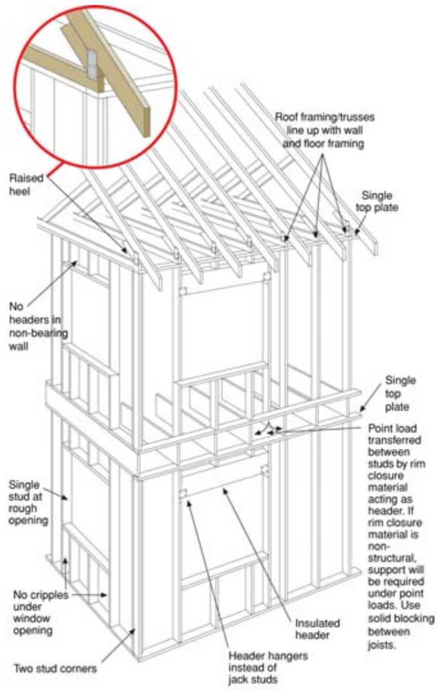
Plate	36'-0"	2
Stud	8'-0"	20
Jack	7'-9 1/4"	6
Jack 2	6'-8 1/2"	2
Cripple 2	1'-2 3/4"	2
Cripple 3	2'-1"	3

Gross wall area	327 ft^2
Window area	74 ft^2
Opaque area	45.17 ft^2
Cavity area	207.83 ft^2

Wall 1 (2x6 16"o.c.)

Plate	36'-0"	3
Stud	8'-8 1/2"	29
Jack	7'-8 1/2"	6
Jack 2	6'-8 1/2"	2
Cripple 1	0'-2 3/4"	6
Cripple 2	1'-2 3/4"	2
Cripple 3	2'-1"	8

Gross wall area	327 ft^2
Window area	74 ft^2
Opaque area	65.60 ft^2
Cavity area	181.40 ft^2



Roof framing/trusses line up with wall and floor framing
Raised heel
Single top plate
No headers in non-bearing wall
Single top plate
Point load transferred between studs by rim closure material acting as header. If rim closure material is non-structural, support will be required under point loads. Use solid blocking between joists.
Single stud at rough opening
No cripples under window opening
Insulated header
Two stud corners
Header hangers instead of jack studs

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5. Provide for durability by controlling moisture

Why control moisture?

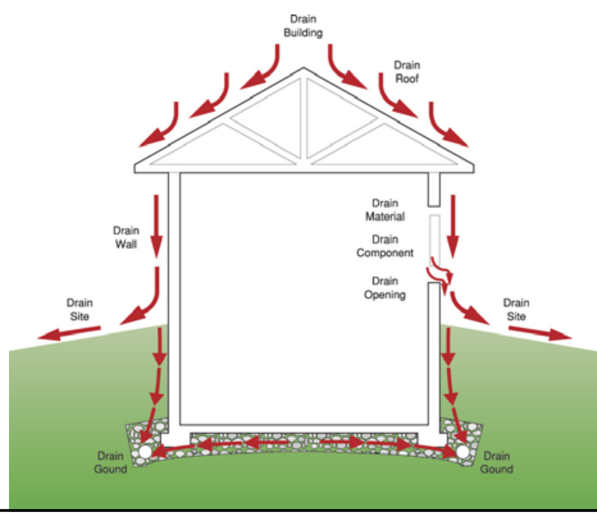
1. Our efforts to save energy and reduce the flow of heat through building assemblies have **reduced drying potentials** and, therefore, increased the importance of controlling moisture flow through building assemblies.

2. Building **materials last longer** when their faces are exposed to similar or equal temperature and humidity.

3. Three things destroy materials in general and wood in particular: **water**, **heat**, and **ultraviolet radiation**. Of these three, water is the most important by an order of magnitude.

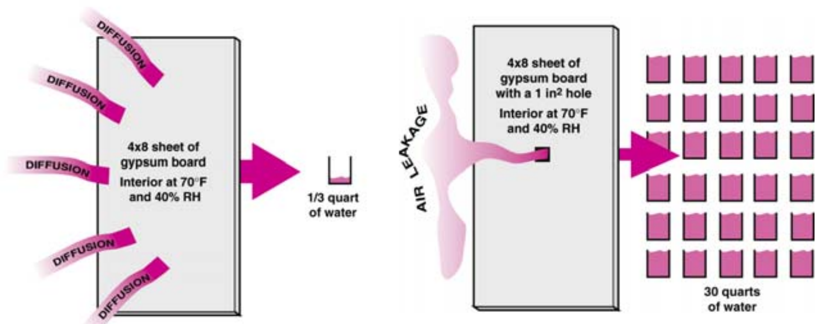
How to control moisture?

In moisture control, the priority is **liquid water first**, particularly when it comes in the forms of rain and groundwater. In these forms it is referred to as "bulk" water.



How to control moisture?

Following are **air-transported vapor** and then **diffusive vapor**, all other things being equal.



55

Remember:

It's always a question of **quantities** and **rates**, of wetting and drying, and the tolerance of materials (individually and in combination) for each and all of the above.

- When the rate of wetting exceeds the rate of drying, **accumulation** occurs.
- When the quantity of accumulated moisture exceeds the storage capacity of the material or assembly, **problems** occur.
- The storage capacity of a material or assembly depends on **time**, **temperature**, and the **material** itself.

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Fungal growth = bad “green” building

57

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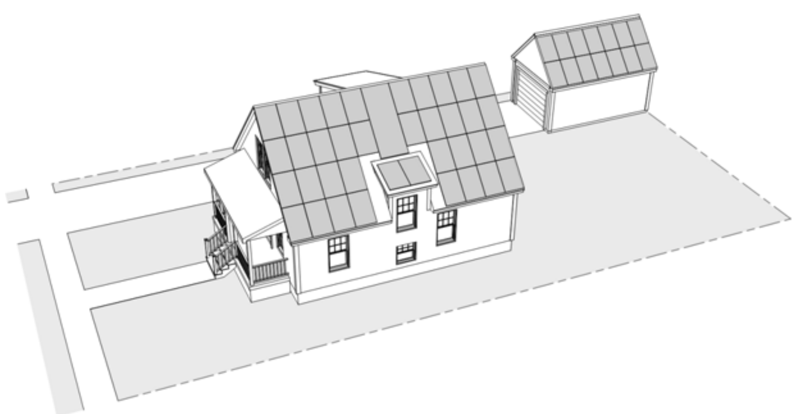
6. Design a roof that is sloped to the south

Plan to use the available solar resource



These two roofs total about 900 sq.ft. of south sloping roof and can accommodate about a 9 kW PV system and 40 sq. ft. of SHW panels . . . but the roof needs to face the right direction!

But the loads must be minimized first

Recall the three general steps:

Step 1: Reduce Enclosure Energy Use

Step 2: Reduce Mechanical System Energy Use

Step 3: Add Site Generated Energy

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Roof area is a future resource

63

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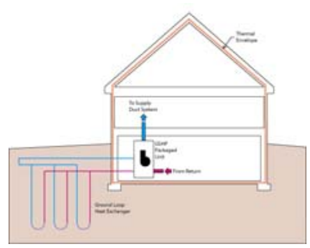
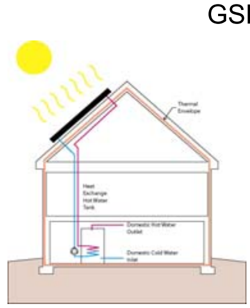
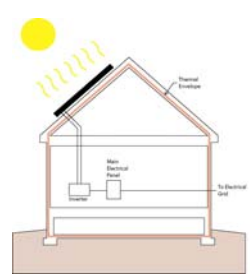
On-site Renewable Energy



GSHP Schematic



Solar Hot Water Schematic



Photovoltaic Schematic

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Summary of the Design approach

Top ten elements in the design of high performance homes:

1. Design for comfort with as little added energy as possible
2. Built tight
3. Ventilate
4. Use more insulation
5. Provide for durability by controlling moisture
6. Design a roof that is sloped to the south
7. Use the most efficient equipment the project can afford
8. Use efficient lighting, appliances and match to occupant needs
9. Reduce energy use 40-70% before adding onsite energy generation
10. Commission mechanical and onsite energy systems

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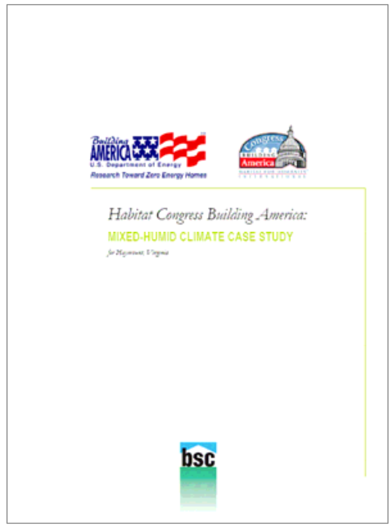
Resources

Building Science Corporation

Designs that Work – Mixed-Humid Climate Case Study

find this at:

www.buildingscience.com/dtw



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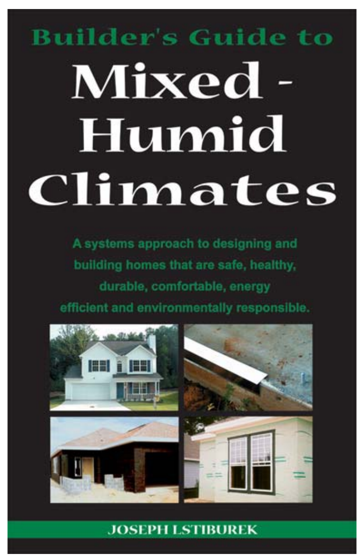
Resources

Building Science Corporation

Builder's Guide to Mixed-Humid Climates

find this at:

www.buildingsciencepress.com



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Resources

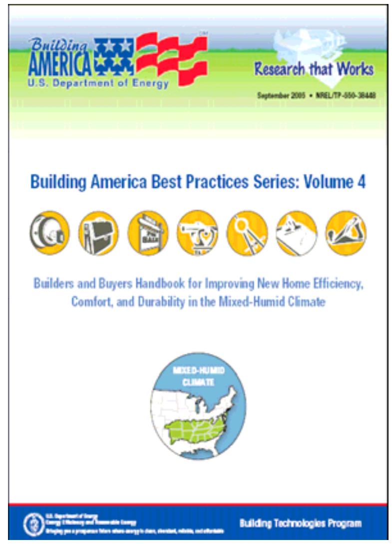
Building America

Mixed-Humid Climate Best Practices Guide

find this at:

www.buildingamerica.gov

(look for "publications")



Rebuilding Greensburg

A Seminar Series on Affordable, Energy Efficient Construction Techniques

Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

Part 1: House Design and Foundation Systems

Date: September 8, 2007

- An overview of energy efficient and affordable house design
- Foundations and rainwater management

Part 2: Framing

- Advanced framing techniques
- Choosing the right windows and doors

Part 3: Mechanical Systems and Airtightness

- Build tight, ventilate right
- Mechanical system design and selection

Part 4: Enclosure

- Insulation – theory and installation practices
- Exterior cladding systems

Part 5: Finishes, Testing and Commissioning

- Measuring building performance
- Whole house commissioning and homeowner training

Questions?

Before you go . . .

- **Sign up sheet for builders**

B.6 Building for Energy Efficiency – Part 2

Steve Bolibruck
IBACOS

IBACOS

Building for Energy Efficiency 2:

How to design the mechanical system for a home that uses less energy at little or no additional cost

Steve Bolibruck

REBUILDING GREENSBURG… *as a healthy, energy efficient, affordable town*

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IBACOS

Session Objectives

- Understand the basic differences between the mechanical system in a standard home compared to a high performance home
- Learn the fundamentals of good residential air distribution system design in high performance homes
- Learn about air distribution system methods appropriate for high performance homes

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Introduction

- High performance homes have different space conditioning requirements
- Standard air distribution system design, selection, and installation practices don't address high performance homes fully
- Need to engineer and install the air distribution system for improved air delivery at lower cfm
- Design and installation of the mechanical system in a high performance home helps a builder stay cost neutral

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High Performance Homes

- So what is different?
  - Improved thermal enclosure leads to reduced heating and cooling loads which results in smaller HVAC equipment
  - Used to use 400 sqft / ton as an estimation of size
  - Now 600 and up to 1000 sqft / ton
  - Improved thermal enclosure also reduces the need for perimeter air delivery
  - Reduced amount of airflow in the system
  - Standard to oversized ducts result in lower velocities
  - Lower velocities at diffusers reduce throw and mixing
  - Impact of duct leakage is amplified

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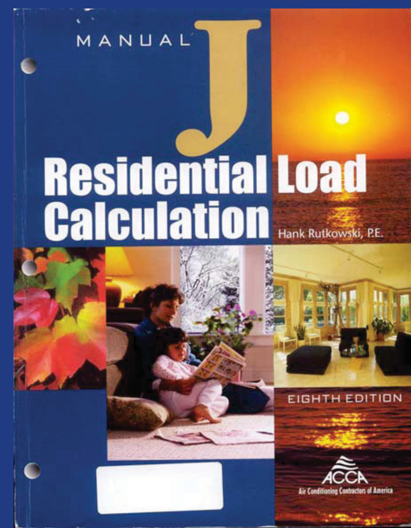
Manual J 8th Edition

- Procedure used to estimate the heat loss and gain of conventional residential structures for the purpose of HVAC sizing
- Determine room-by-room loads

- Manual J examines:
  - Enclosure elements
  - Air leakage
  - System losses / gains
  - Sun position
  - Latent and internal gains



Manual J – Heat Loss

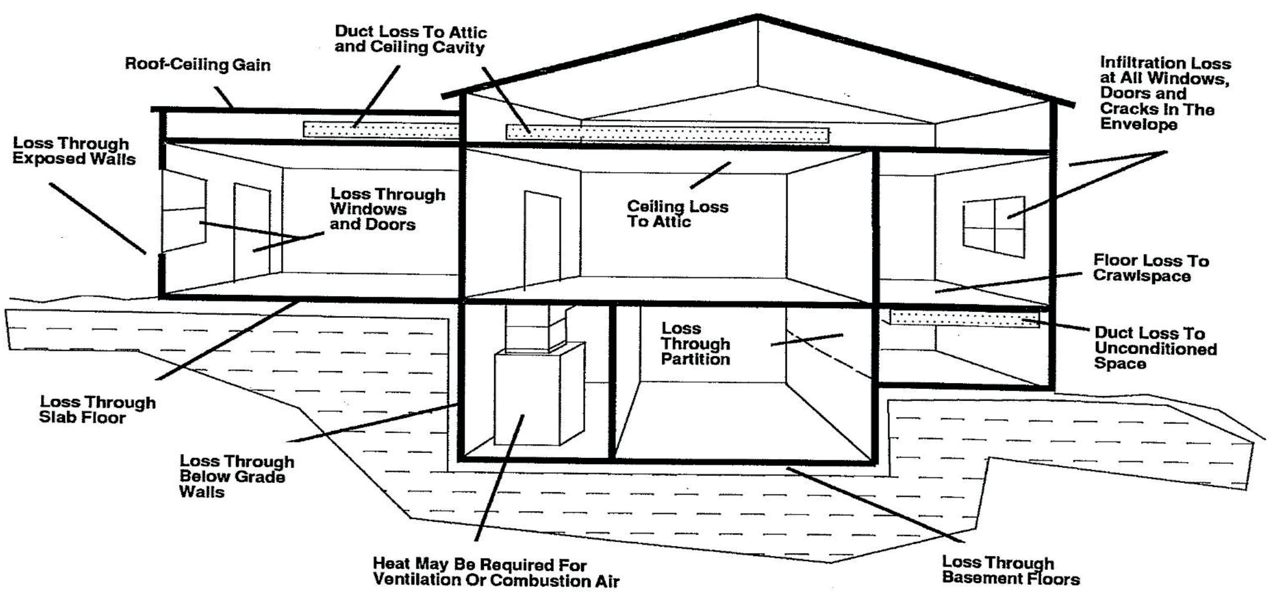


Figure 1-1

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Manual J – Heat Gain

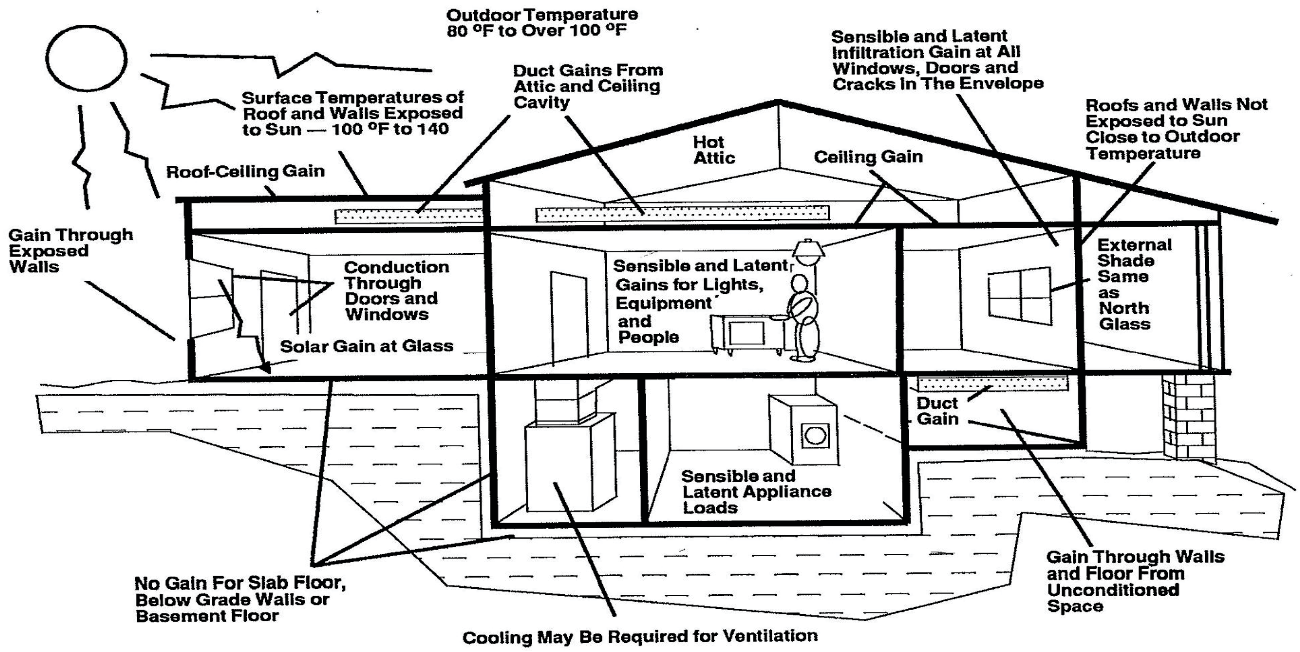

Figure 1-2

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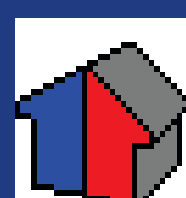
Load Calculation Software

- Highly recommended
  - Wrightsoft
  - Elite RHVAC
  - ASHRAE
- Easy to use
  - Enter data
  - Self calculating
  - Draw building and software tallies load
- Have to know the procedure and understand the process to trust the output.



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Manual S – Equipment Selection

- Bridge between Manual J and Manual D
- Obtain detailed manufacturer's information and review it to be sure you have what you need
  - Detailed capacities for heating & cooling equipment
  - Combination ratings for cooling & heat pumps
  - Evaporator coil info
  - Fan performance info at different speeds & external static pressures

Equipment Selection Example

Manual J

- Peak Heating and Cooling House Loads
- Room-by-Room Loads & Required Airflows

Manual J Loads	
Total required heating output	65,540
Required sensible cooling output	29,362
Required total cooling output	36,058

Newhouse — Manual J calculations — back of house facing east, inground basement, bay window options

	Peak Heating Load			Peak Cooling Load		
Room	BTUH	% of total	CFM	BTUH	% of total	CFM
Study	4,033	6.2%	82	1,033	2.9%	39
Rec Room	8,571	13.1%	175	1,878	5.2%	71
Bath	168	0.3%	3	94	0.3%	4
Storage	3,025	4.6%	62	563	1.6%	21
Family	6,722	10.3%	137	5,540	15.4%	210
Kitchen/Nk	4,201	6.4%	86	4,226	11.7%	161
Dining	4,705	7.2%	96	2,348	6.5%	89
Living	4,873	7.4%	99	2,441	6.8%	93
Foyer	1,512	2.3%	31	939	2.6%	36
Library	2,689	4.1%	55	1,409	3.9%	54
Pwdr	168	0.3%	3	188	0.5%	7
Mstr Suite	7,898	12.1%	161	4,319	12.0%	164
Dressing	1,849	2.8%	38	1,127	3.1%	43
W.I.C	1,344	2.1%	27	845	2.3%	32
Util	168	0.3%	3	188	0.5%	7
Bed2	4,033	6.2%	82	2,535	7.0%	96
Bath	672	1.0%	14	470	1.3%	18
Bed3	3,529	5.4%	72	2,348	6.5%	89
Hall	1,849	2.8%	38	1,221	3.4%	46
Bed 4	3,529	5.4%	72	2,348	6.5%	89
not used	0	0.0%	0	0	0.0%	0
Totals	65,540	100.0%	1,335	36,058	100.0%	1,370

Equipment Efficiency

- Use the most efficient equipment the project can afford
  - Conduct iterative energy analysis to determine the impact of equipment efficiencies on energy savings
  - Translate the energy savings into cost reduction and look at the initial cost of the equipment upgrades

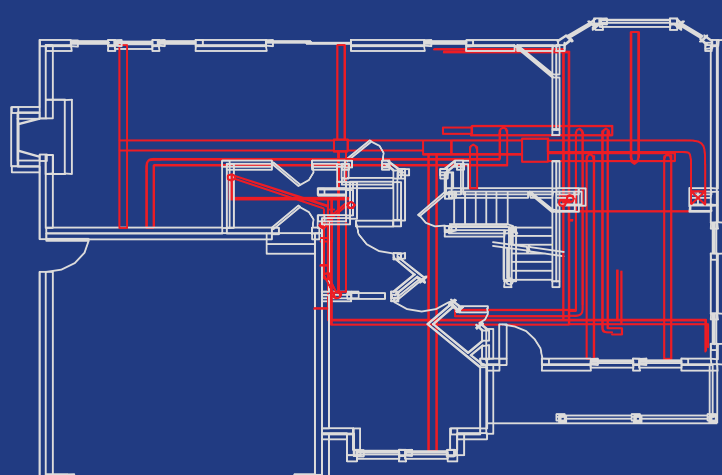
Equipment Efficiency

- Common Industry Terminology:
  - Energy Efficiency Ratio (EER) = Btuh of cooling / watts used
  - Seasonal Energy Efficiency Ratio (SEER) = Btu cooling produced / watt-hour used
  - Annual Fuel Utilization Efficiency (AFUE) = The % of the amount of energy consumed that is actually converted to useful heat

Standard Systems

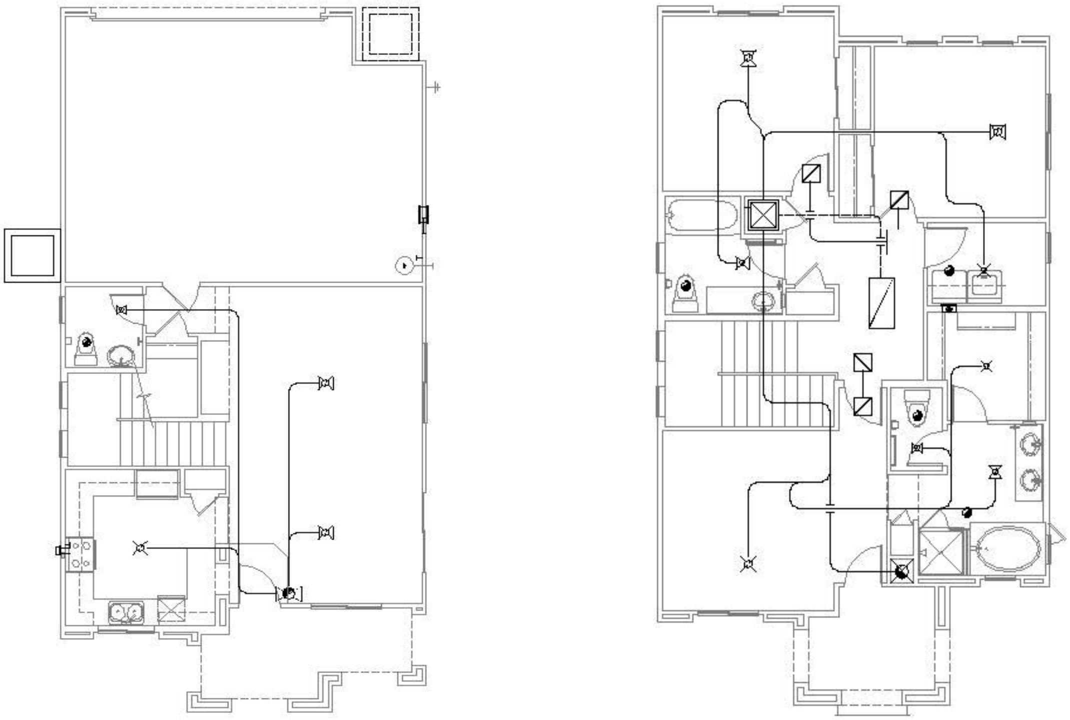
- Standard thermal enclosure requires larger mechanical equipment that may even be oversized
- Multiple supply trunks with long branches routed to the perimeter of the thermal enclosure
- Poor return strategies
- Ductwork is not sealed and is therefore leaky
- More energy is consumed and less comfort is delivered

Standard Systems



- No integration with the other aspects of the house
- Perimeter delivery of supply air
- Room by room returns or worse

Standard Systems



IBACOS

High Performance Air Distribution Design

- Use ACCA's Residential Duct System Manual D
- Integrate the distribution system into the floor plan of the house
- Locate equipment and ducts in conditioned space
- Size system for balanced air flows and quite operation
- Use central return systems
- Understand duct design is an iterative, back and forth process: velocity, friction, throw, diffuser…

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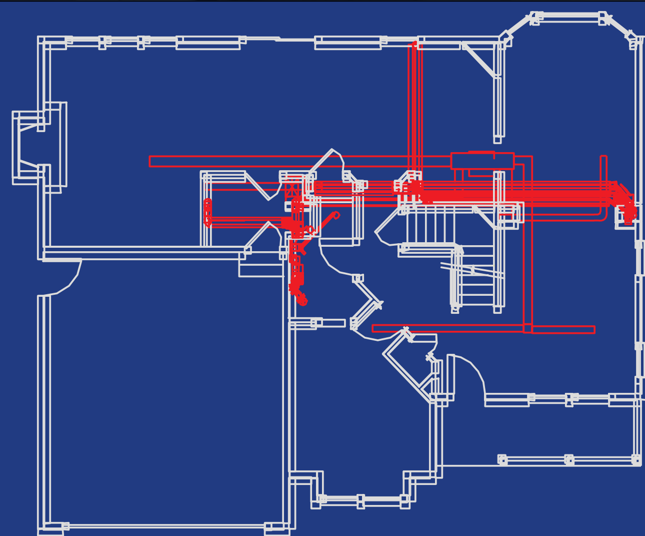
IBACOS

High-Performance System

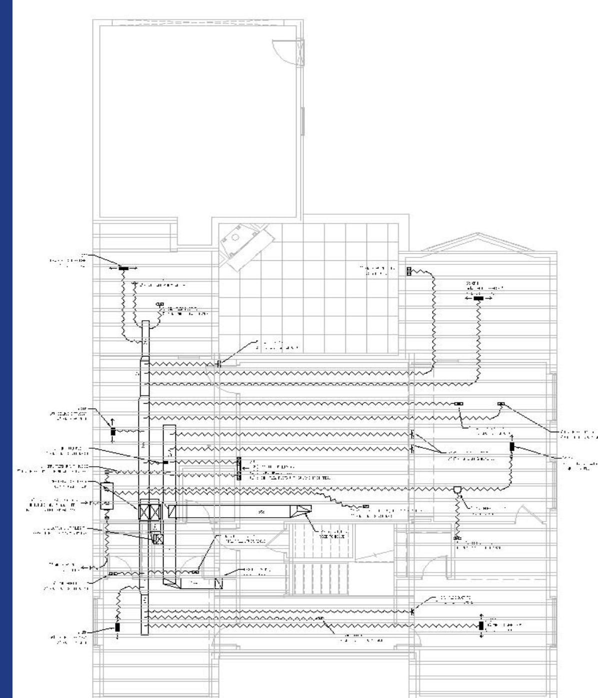


- Fully engineered and integrated design
- Centerline supply with high sidewall distribution
- Central return with jump ducts or transfer grilles

IBACOS

High-Performance System

- Equipment and ductwork in conditioned space
- Short and efficient supply distribution
- Central returns
- Reduced total equivalent length utilizing shorter and more straight trunks and branches
- Right-sized ducts deliver air at needed velocities



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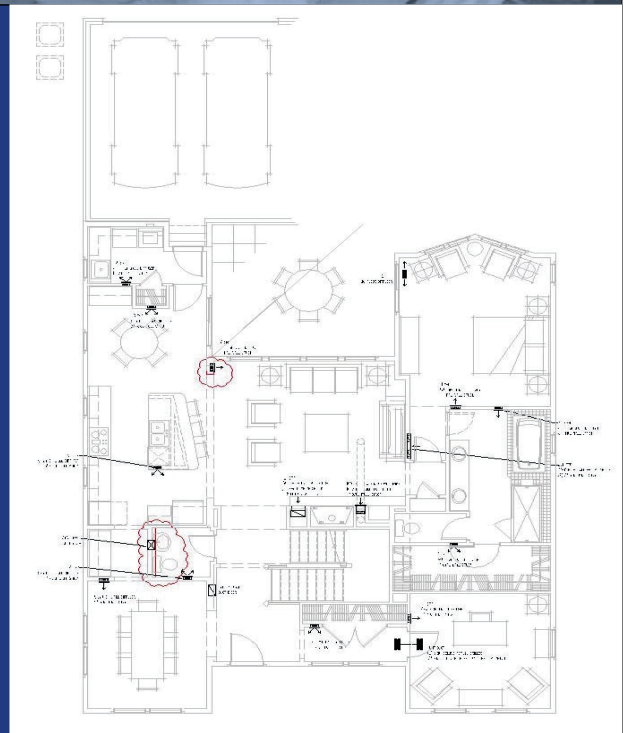
IBACOS

High-Performance System

- Relatively open floor plan reduces the amount of wall space available
- Use of high sidewall diffusers more centrally located to reduce duct length
- Central return to optimize air distribution system
- Transfer grilles used to connect enclosed rooms



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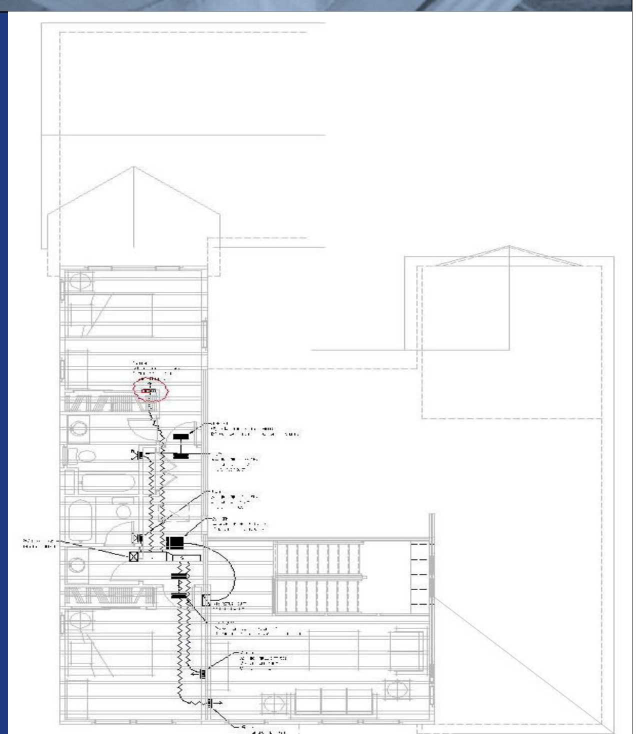
IBACOS

High-Performance System

- Supply and return risers routed from the basement
- Short and compact supply trunk in the second floor structure.
- High sidewall diffuser locations to reduce the duct length as much as possible
- Central return with transfer grilles
- Right-sized ducts deliver air at needed velocities



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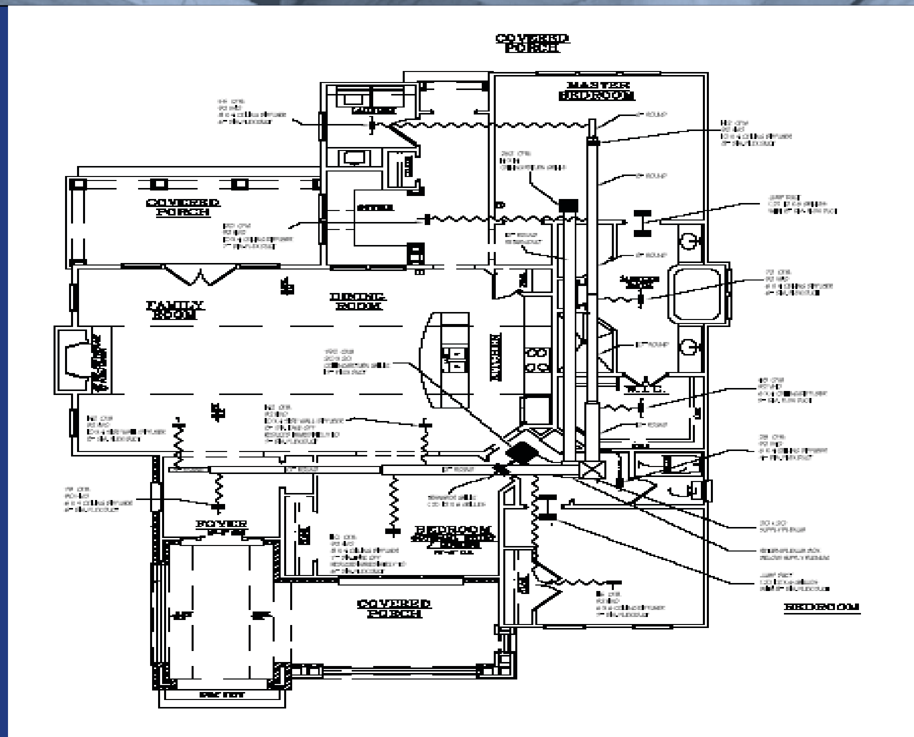
High-Performance System



Duct Sealing

- No conventional duct tape
- Use of UL 181 rated duct mastic on all joints and seams
- Seal all ductwork even in conditioned space.

IBACOS

What To Look For

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IBACOS

Diffuser Selection and Design

Diffuser Comparisons

Room Designation	Throw Desired	CFM	Desired Selection VHO & HVO		Contractor Selection 6" x 10" & 6" x 12"		Generic Selection RZ682	
			Size	Throw	Size	Throw	Size	Throw
Laundry	4'	55	8 x 4	6.6'	6 x 10	3.6'	8 x 4	6.6'
Bedroom/Study	4.5'	110	8 x 4	13.3'	6 x 10	9.6'	6 x 10	9.1'
Family Rm	16'	142	10 x 4	15.8'	6 x 10	12.4'	6 x 10	9.1'
Family Rm	16'	142	10 x 4	15.8'	6 x 12	10.9'	6 x 10	9.1'
Mstr. Bath	7.5'	72	6 x 4	9.7'	6 x 10	6.3'	6 x 6	8.1'
Mstr. Bed	7.8'	142	10 x 4	12.3'	6 x 10	9.6'	8 x 8	11.2'
Office	7'	120	10 x 4	13.4	6 x 10	10.5'	12 x 4	11.5

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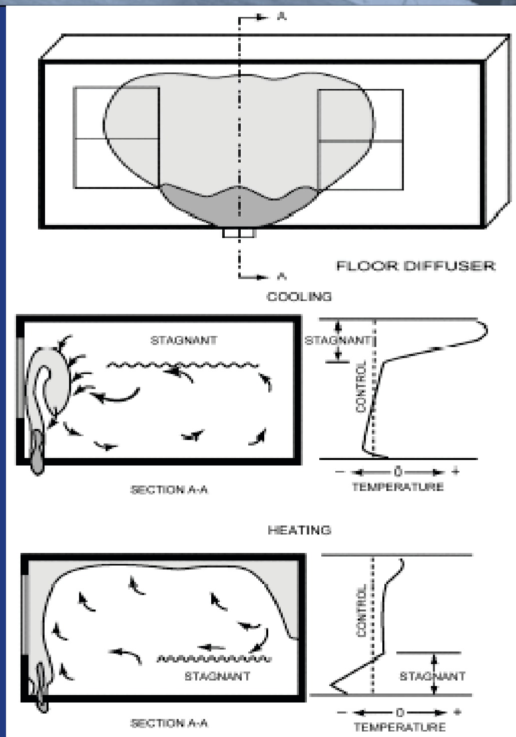
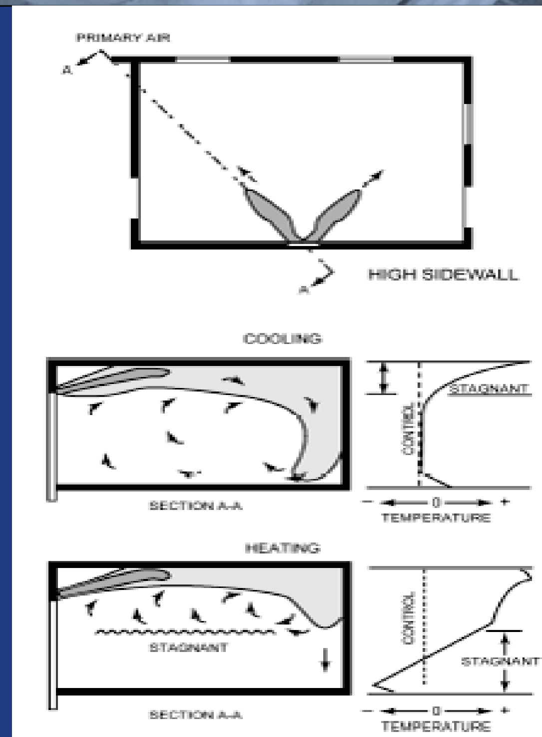
Diffuser Selection and Design





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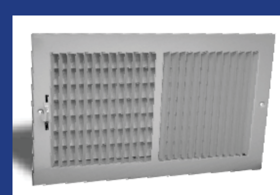
IBACOS

Diffuser Test Plan

Supply Outlets

Adjustable-Blade Single Deflection



Fixed-Blade 2-Way Throw

High-Velocity Slot

Adjustable-Blade Double Deflection

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IBACOS

System Commissioning

- No conventional duct tape
- Use of UL 181 rated duct mastic on all joints and seams
- Seal all ductwork – even in conditioned space.
- Leakage of the system should be less than 5% of the fan capacity

IBACOS

System Commissioning

Verify fan performance and system flows

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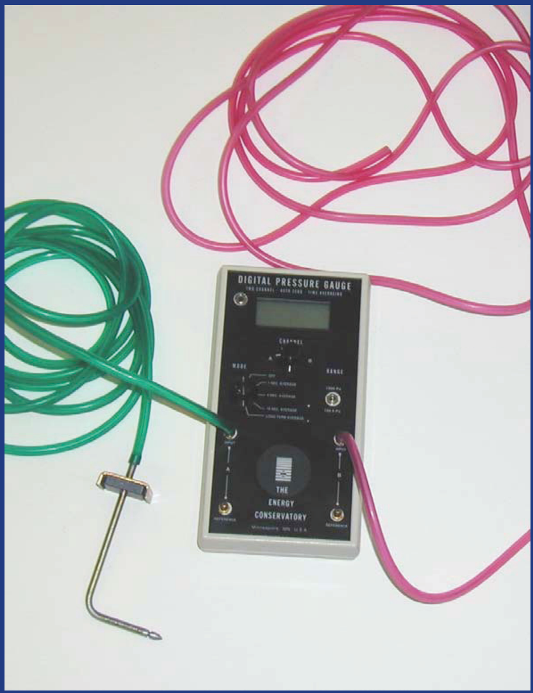
System Commissioning

Use flow hood measurements to balance, based off measured total flow

IBACOS

System Commissioning

Measure adequacy of pressure balancing and return strategy



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B.7 Building for Energy Efficiency – Part 3

Alex Lukachko
Building Science Consulting

Building for Energy Efficiency – Part 3

Design details and construction drawings for energy efficient homes

Alex Lukachko
Building Science Consulting LLC
www.buildingscience.com

Building America

The U.S. Department of Energy's Building America Program is reengineering the American home for energy efficiency and affordability. Building America works with the residential building industry to develop and implement innovative building processes and technologies – innovations that save builders and homeowners millions of dollars in construction and energy costs. This industry-led, cost-shared partnership program uses a systems engineering approach to reduce energy use, utility bills, construction time, and construction waste.

For more information, visit our website at:
www.buildingamerica.gov

Objectives for this afternoon . . .

1. "Show off" our house plans as examples of affordable, energy efficient, and durable construction
2. Explain applied building science principles through details and construction photos

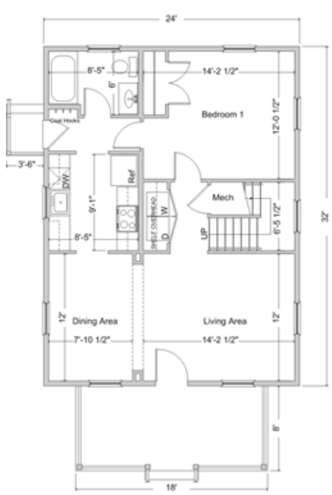
Overview of the Design approach

Top ten elements in the design of high performance homes:

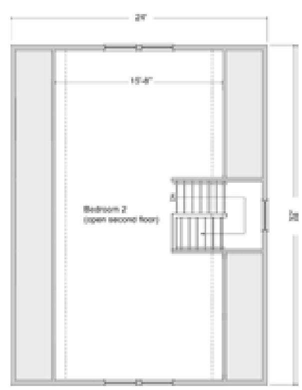
1. Design for comfort with as little added energy as possible
2. Built tight
3. Ventilate
4. Use more insulation
5. Provide for durability by controlling moisture
6. Design a roof that is sloped to the south
7. Use the most efficient equipment the project can afford
8. Use efficient lighting, appliances and match to occupant needs
9. Reduce energy use 40-70% before adding onsite energy generation
10. Commission mechanical and onsite energy systems

Greensburg - Plan 1

Greensburg Plan 1 – Floor Plans



First Floor Plan

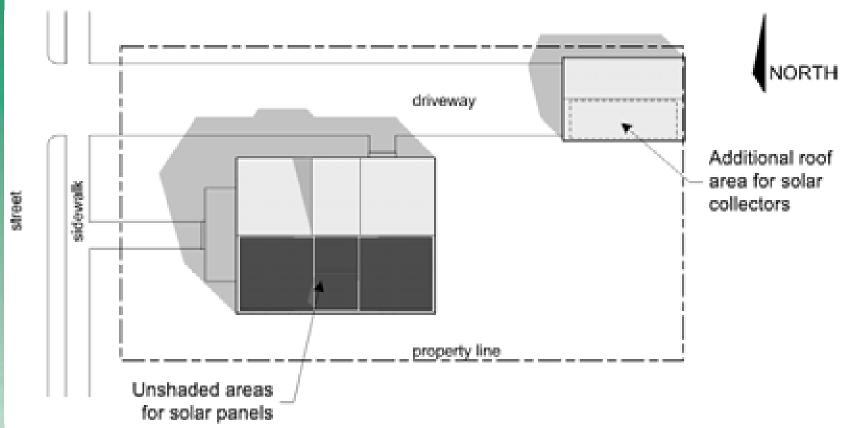


Second Floor Plan

(showing unfinished option,
Alt. 2 br, 1 bath with dormer)

1250 sq ft, 2-bedroom, 1.5 story single family home, with basement

Siting, Orientation and Solar Access



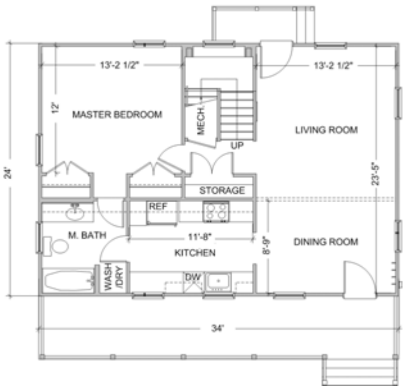
- Expansive south-facing roof for solar access
- Large overhangs and landscaping shade house to reduce summertime cooling loads

7

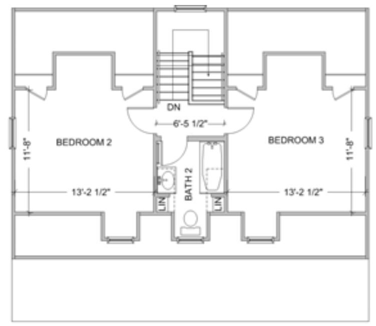
Greensburg - Plan 2

8

Greensburg Plan 2 – Floor Plans



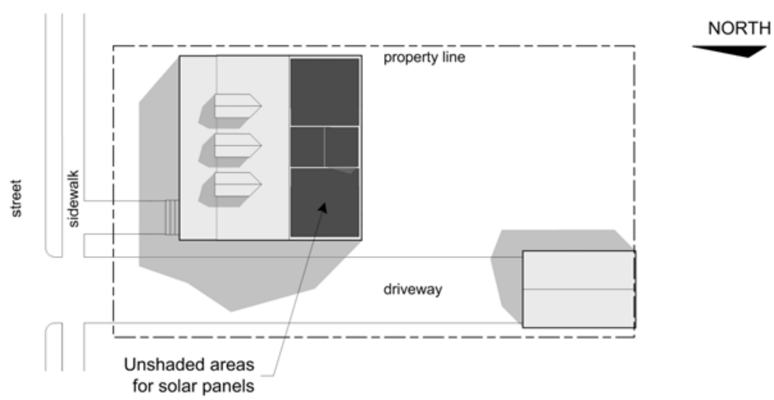
First Floor Plan



Second Floor Plan

1255 sq ft, 3-bedroom, 1.5 story single family home with basement

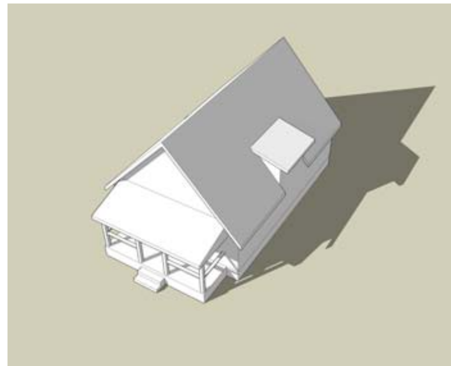
Siting, Orientation and Solar Access



- Expansive south-facing roof for solar access
- Large overhangs and landscaping shade house to reduce summertime cooling loads

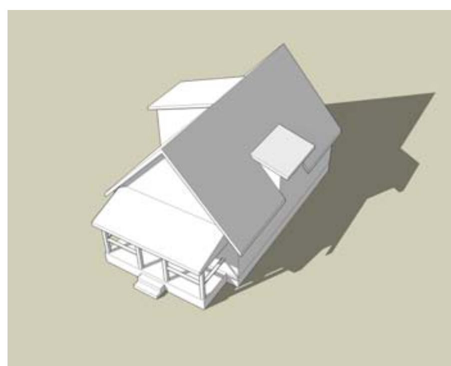
Adding to the Basic Plan

House Plan	**Greensburg Standard**	
Description	Two-bedroom house with living area on the main floor. Second floor can be divided into two bedrooms and bath.	
Living Area	Ground Floor	750 sq ft
	Second Floor	500 sq ft
	Total	**1250 sq ft**
Bedrooms	Ground Floor	1
	Second Floor	1
	Total	**2**
Number of Bathrooms		1



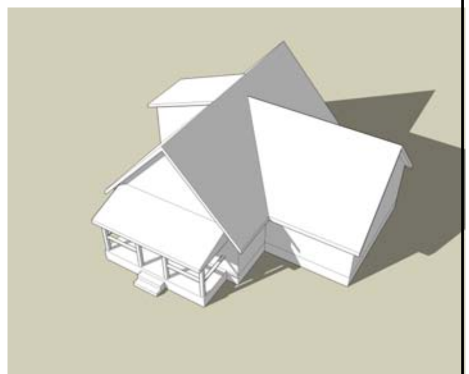
Adding to the Basic Plan

House Plan	**Greensburg Plus**	
Description	Three-bedroom version of the Standard with a second bathroom under a new dormer.	
Living Area	Ground Floor	750 sq ft
	Second Floor	500 sq ft
	Total	**1250 sq ft**
Bedrooms	Ground Floor	1
	Second Floor	2
	Total	**3**
Number of Bathrooms		2



Adding to the Basic Plan

House Plan	**Greensburg "L"**	
Description	Three-bedroom house with "Great Room" and study on the ground floor, 3 bedrooms and second bath on the second floor.	
Living Area	Ground Floor	1050 sq ft
	Second Floor	800 sq ft
	Total	**1850 sq ft**
Bedrooms	Ground Floor	0
	Second Floor	3
	Total	**3**
Number of Bathrooms		2



Examples: Royal Township, Michigan

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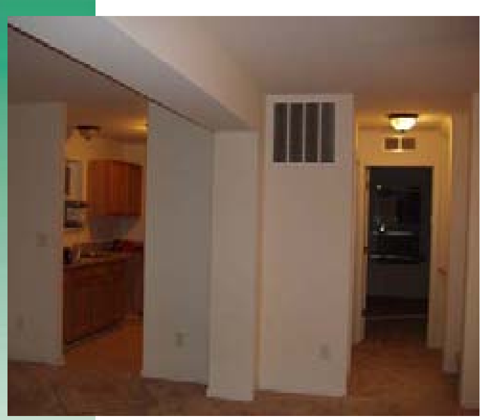
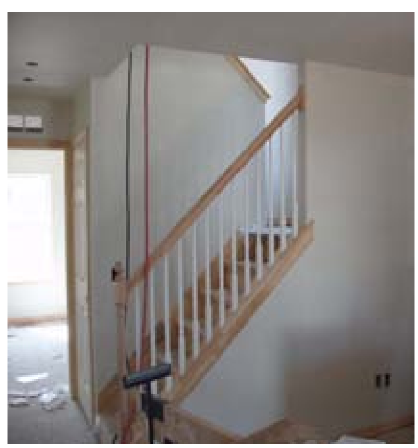
Examples: Carbondale, Colorado



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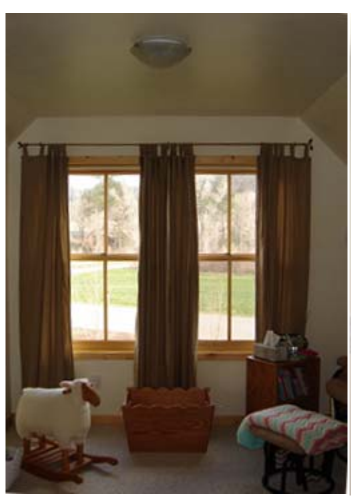

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REBUILDING GREENSBURG HOUSING FAIR

Greensburg, KS

PLAN 1 - THREE BEDROOM - BASEMENT

PROJECT DESCRIPTION

These plans describe an affordable, energy-efficient, and durable 1250 sq ft single-family home. The drawing set and specifications were developed by Building Science Corporation through the Department of Energy's Building America Program for the "Rebuilding Greensburg" Housing Resource Fair on July 19-21, 2007. The plans provide an example of how homes in Greensburg could be rebuilt as part of a healthy, energy efficient and affordable town. During project planning and construction, all efforts should be made to meet the goals of this project.

SQUARE FOOTAGES

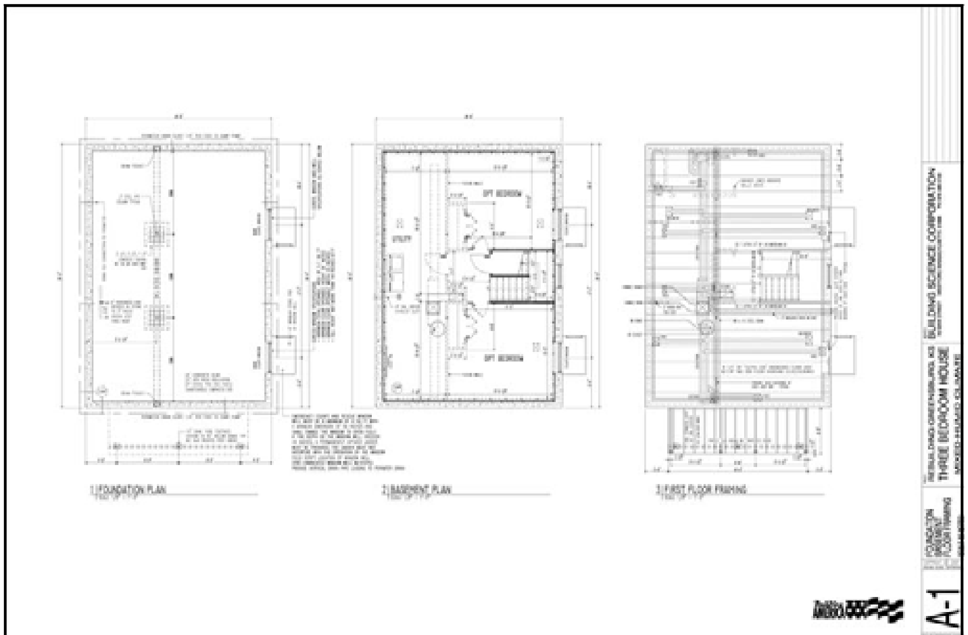
BASEMENT	816 SQ FT
FIRST FLOOR	816 SQ FT
SECOND FLOOR	444 SQ FT

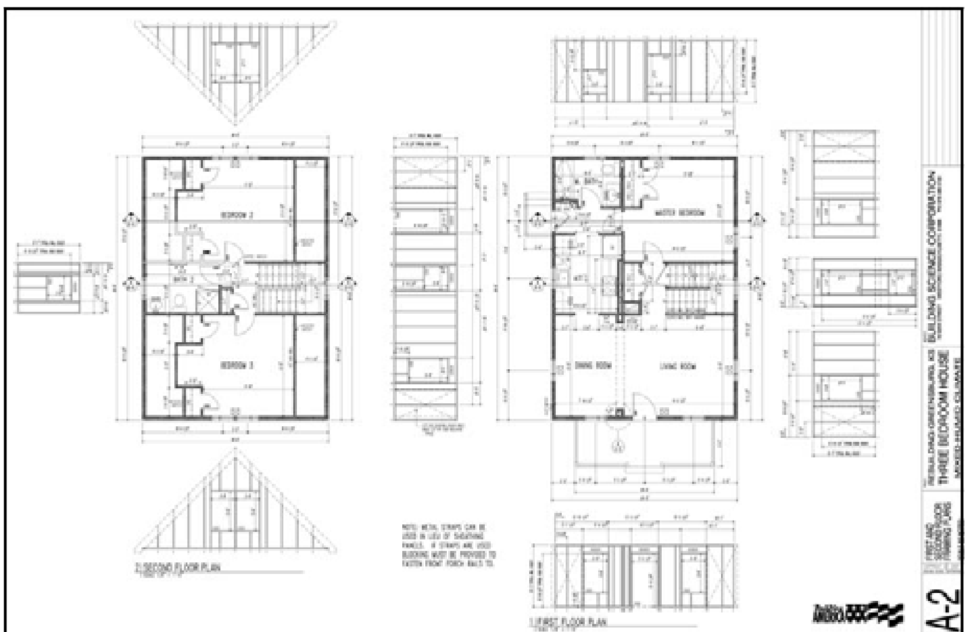
LIST OF DRAWINGS

A-1 FOUNDATION / BASEMENT / FIRST FLOOR FRAMING PLANS
A-2 FIRST AND SECOND FLOOR PLANS / WALL FRAMING ELEVATIONS
A-3 SECOND FLOOR FRAMING / ROOF FRAMING / ROOF PLANS
A-4 BUILDING SECTION AA
A-5 BUILDING SECTION BB / WALL SECTION
A-5 BUILDING ELEVATIONS
A-6 DETAILS
M-1 MECHANICAL PLANS
E-1 ELECTRICAL PLANS

DATE: 19 JULY 2007

BUILDING SCIENCE CORPORATION


1 FOUNDATION PLAN
2 BASEMENT PLAN
3 FIRST FLOOR FRAMING
UTILITY
BUILDING SCIENCE CORPORATION
THREE BEDROOM HOUSE
A-1


BEDROOM 2
BEDROOM 3
MASTER BEDROOM
DINING ROOM
LIVING ROOM
2 SECOND FLOOR PLAN
1 FIRST FLOOR PLAN
BUILDING SCIENCE CORPORATION
THREE BEDROOM HOUSE
A-2

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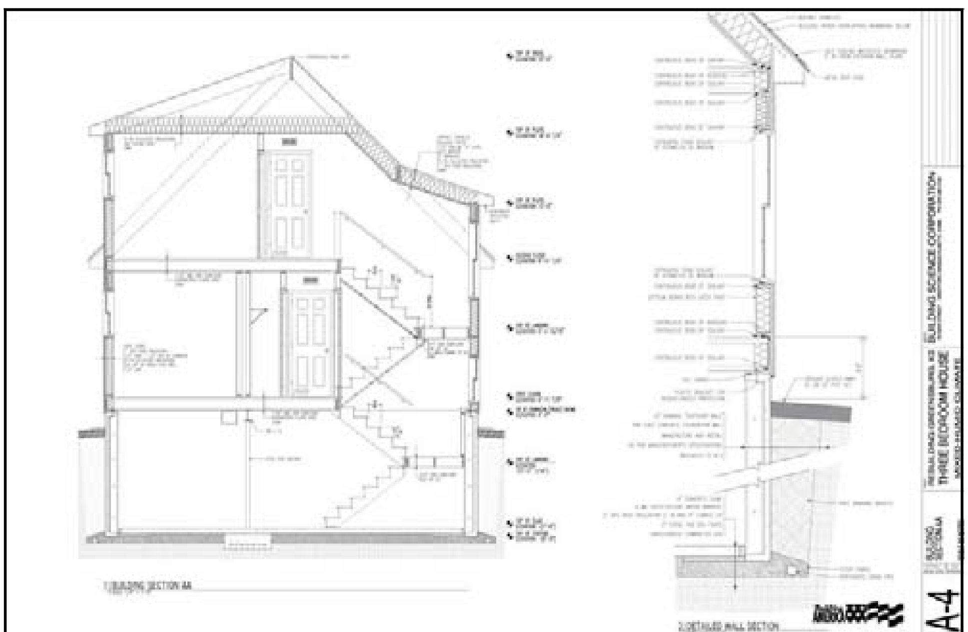

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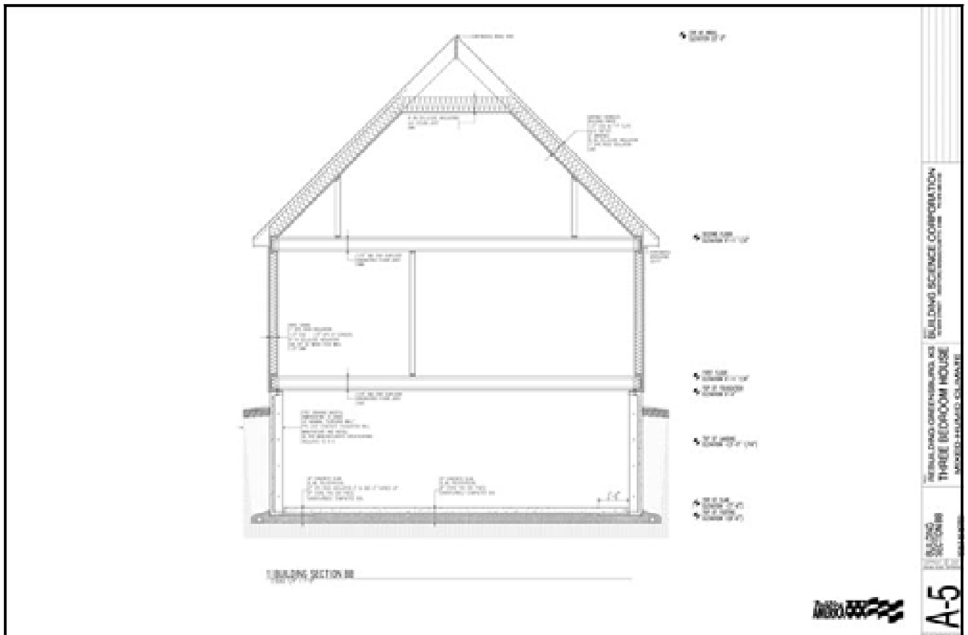

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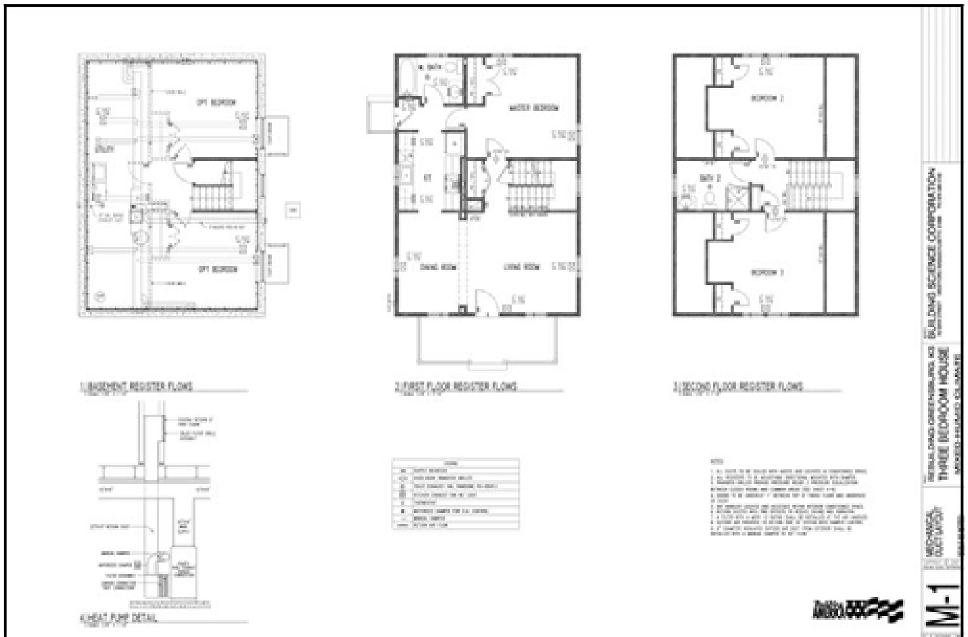
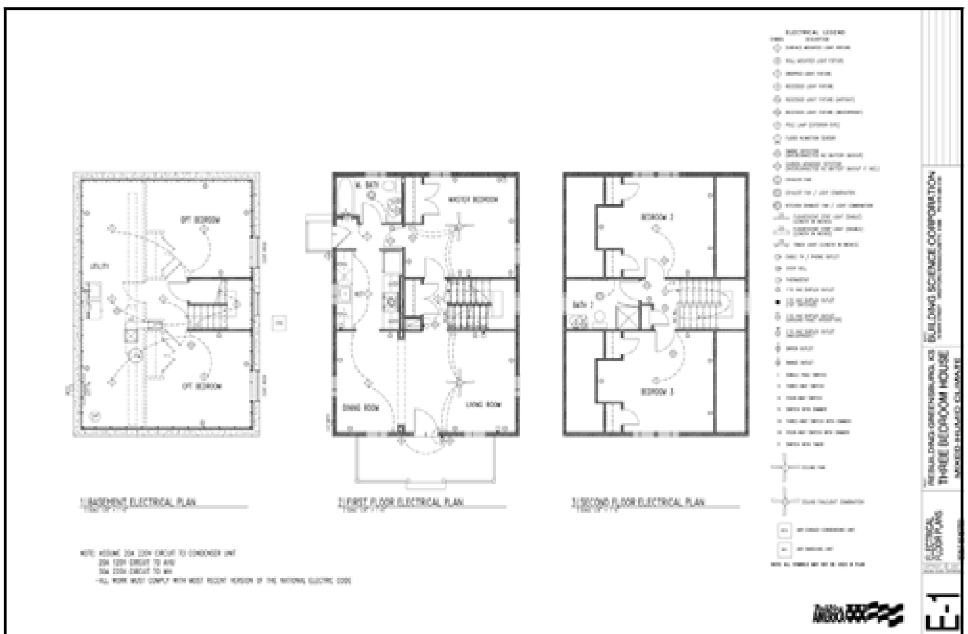


BUILDING SCIENCE CORPORATION
THREE BEDROOM HOUSE
M-1



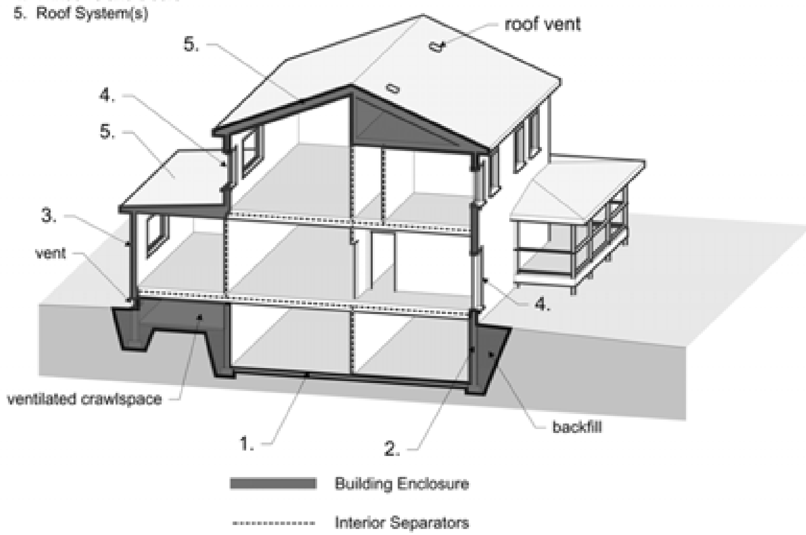
BUILDING SCIENCE CORPORATION
THREE BEDROOM HOUSE
E-1

Building Science Details

- The Building Enclosure
- Rainwater Control
- Airflow Control
- Water Vapor Control
- Thermal Control

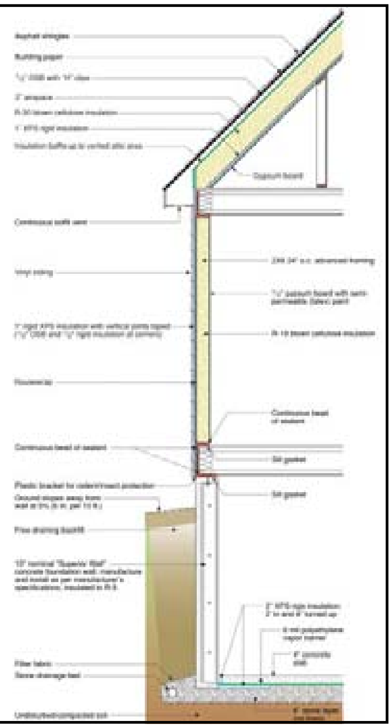
Building Enclosure Components:

1. Basement Floor System(s)
2. Foundation Wall System(s)
3. Above Grade Wall System(s)
4. Windows and Doors
5. Roof System(s)



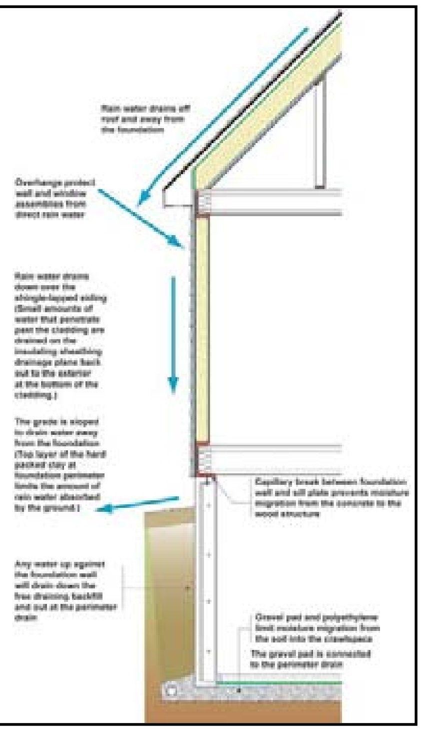
Enclosure Design

	Proposed Assembly
Above grade walls	**R-19, 2x6 frame @ 24” o.c. + R-5 Sheathed Walls**
Roofs	**R-38 Attic / R-35 Cathedral Ceiling**
Windows	**Low-e Windows (U=0.33, SHGC=0.28)**
Below grade walls	**“Superior Wall” Basement**
Airtightness	**BSC BA Airtightness (2.5 ins/100 sf)**

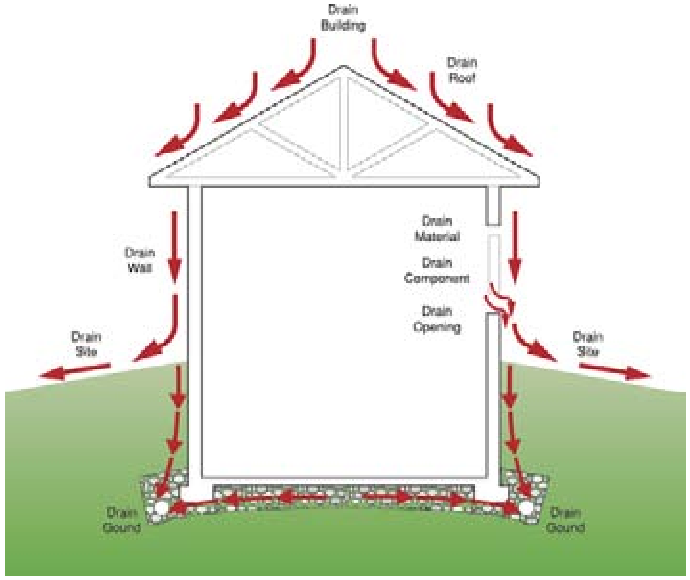


Drainage Profile

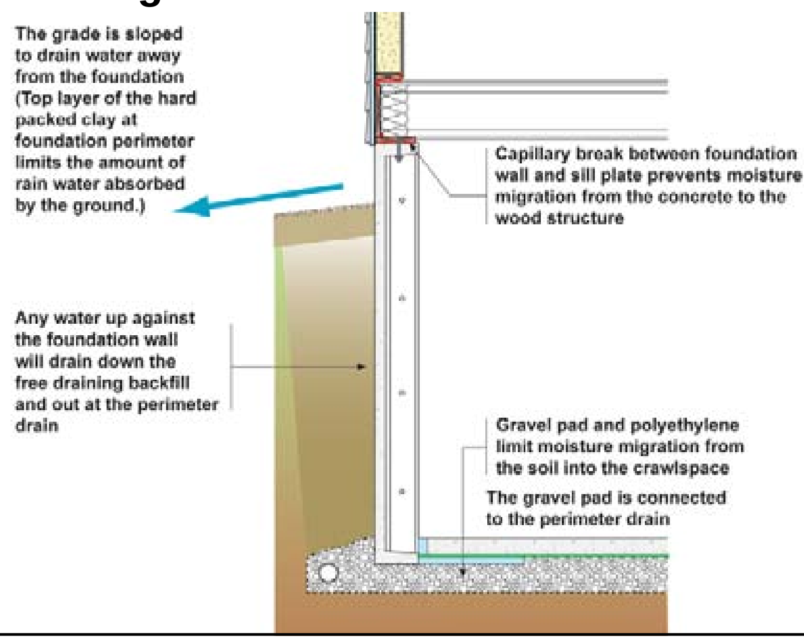
- 12-18” roof overhang
- Use draining exterior cladding
- Complete drainage plane
- Drain water away from building
- Control ground water



Drain Everything

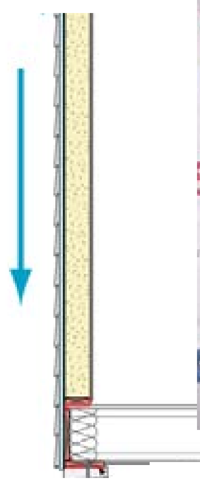


Drainage Profile - Foundation



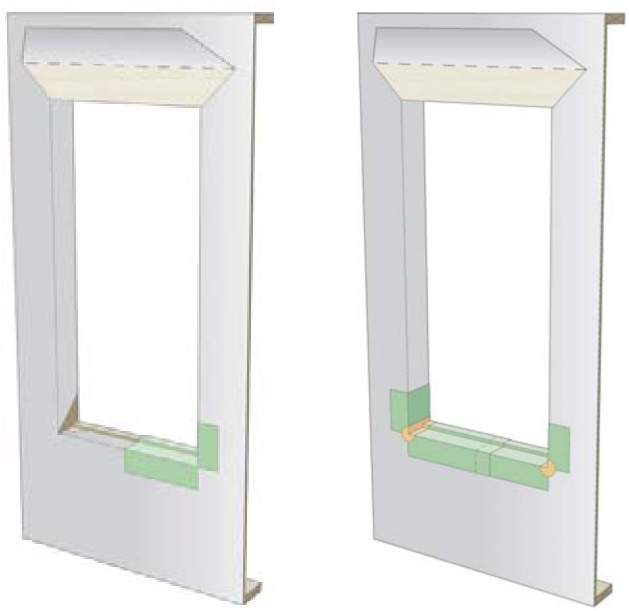
Drainage Profile - Walls

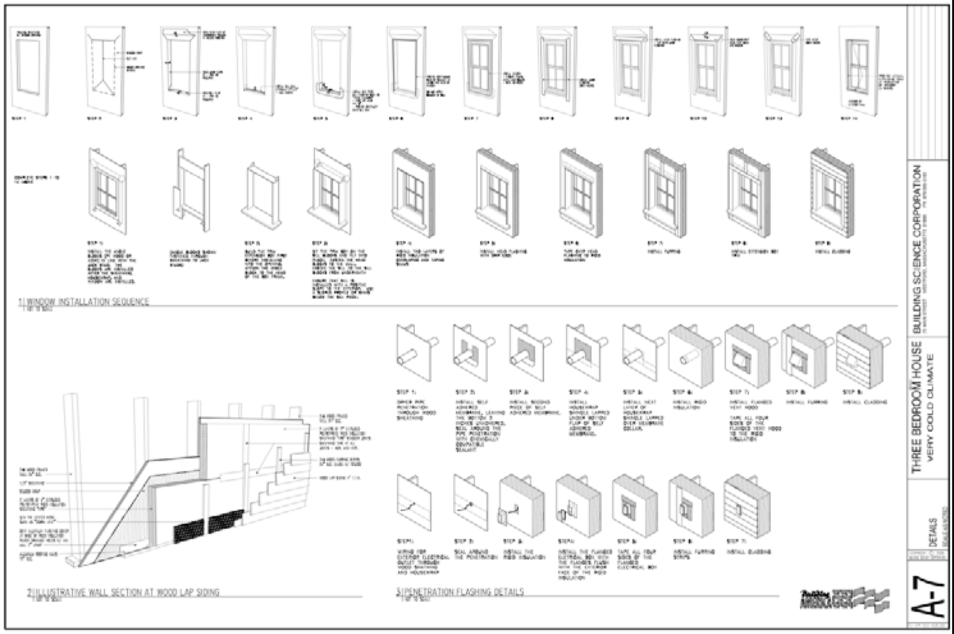
Rain water drains down over the shingle-lapped siding (Small amounts of water that penetrate past the cladding are drained on the insulating sheathing drainage plane back out to the exterior at the bottom of the cladding.)



Windows and other penetrations must be integrated with drainage plane


GRACE VYCOR PLUS
DUPONT





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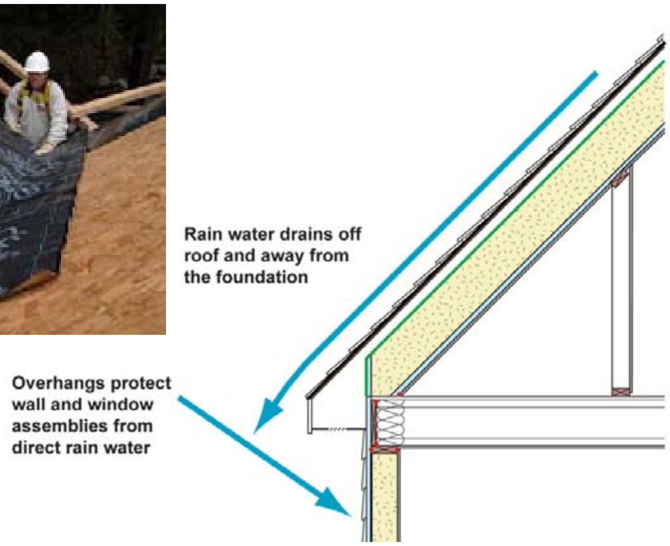
Drainage Profile - Roofs



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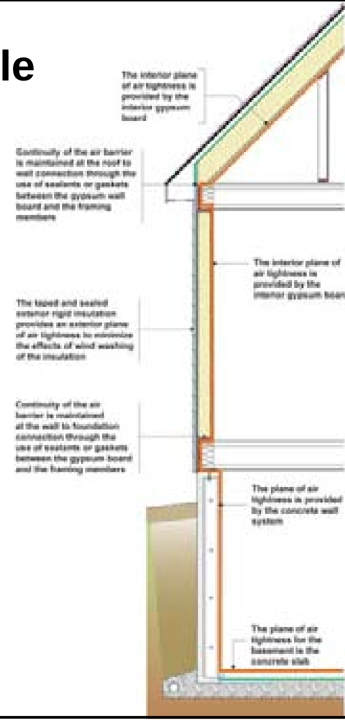
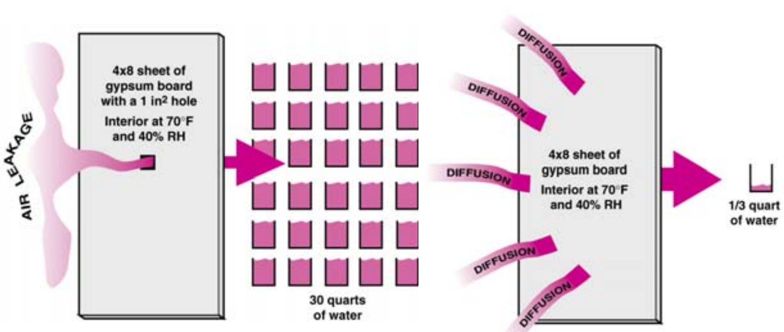
Airflow Control Profile

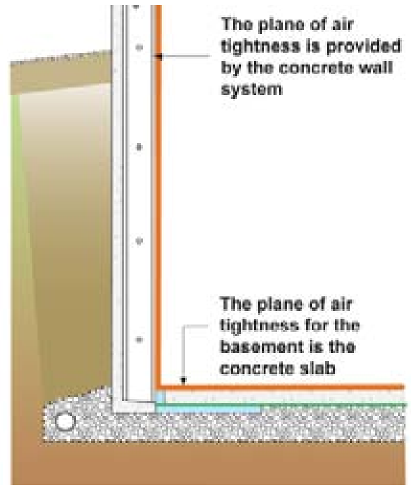
- Continuous interior air barrier with Airtight Drywall Approach
- Additional resistance to airflow - housewrap and exterior sheathing
- Soil gas control
- Airsealing of windows and other penetrations



Air Leakage vs Vapor Diffusion



Airflow Control - Foundation



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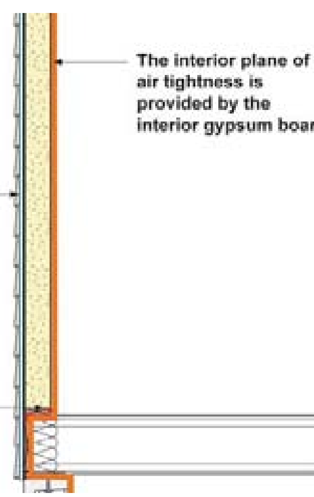
Airflow Control - Walls



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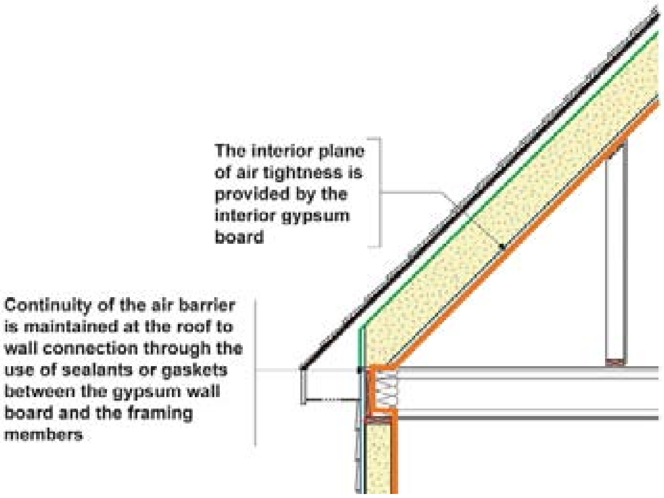
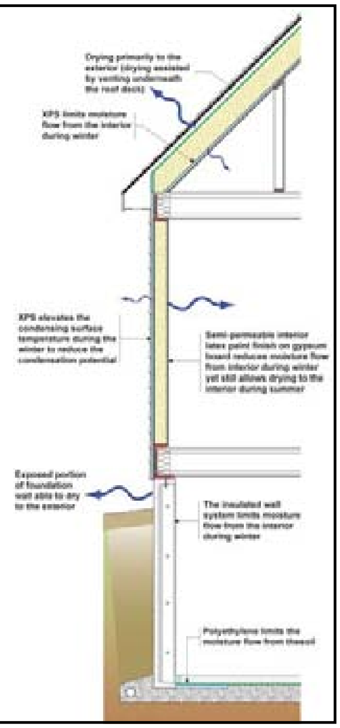
Airflow Control - Roofs

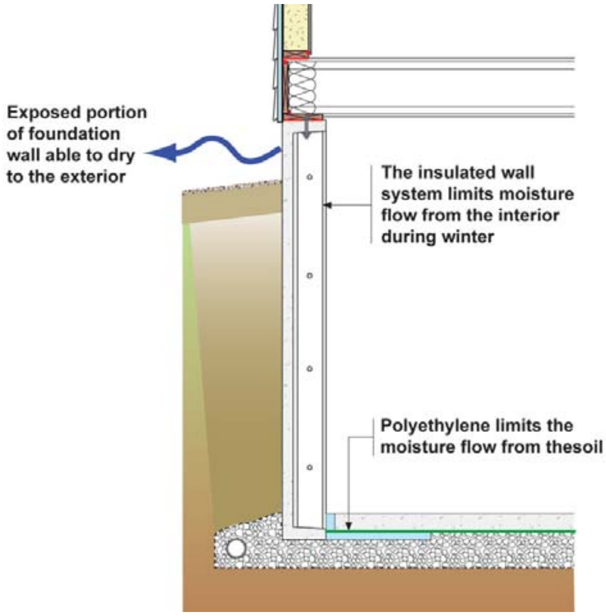


Vapor Control Profile

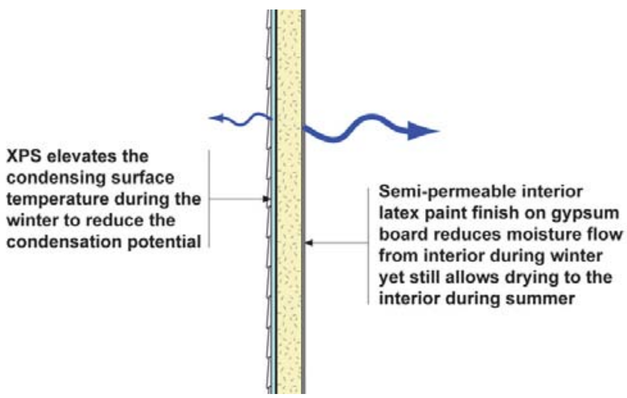
- Mixed-Humid Climate - assemblies need to dry to interior and exterior
- Rigid insulation (XPS) limits moisture flow
- Works with insulation to control surface temperature and reduce condensation potential



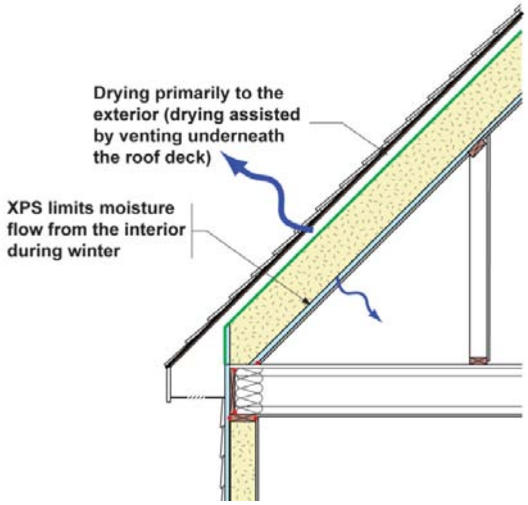
Vapor Control - Foundations

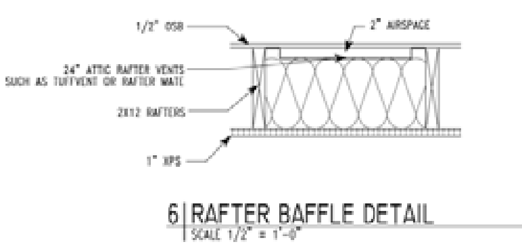


Vapor Control - Walls

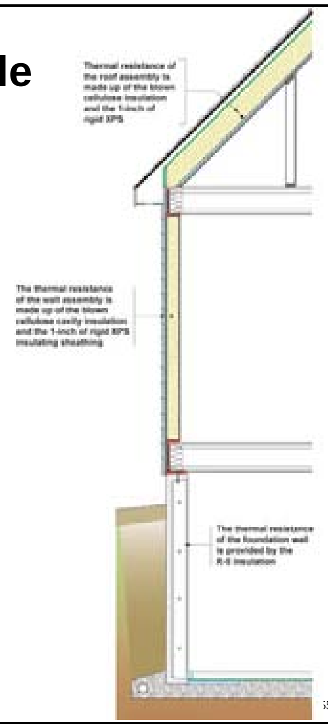


Vapor Control - Roofs



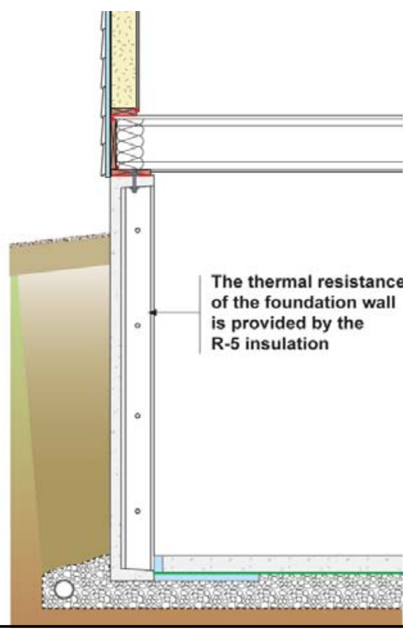


Thermal Control Profile



- Rigid insulation used to control thermal bridging
- Advanced framing techniques used to maximize overall thermal resistance
- Air barrier system and full cavity fill insulation to minimize airflow thermal bypass

Thermal Control - Foundation



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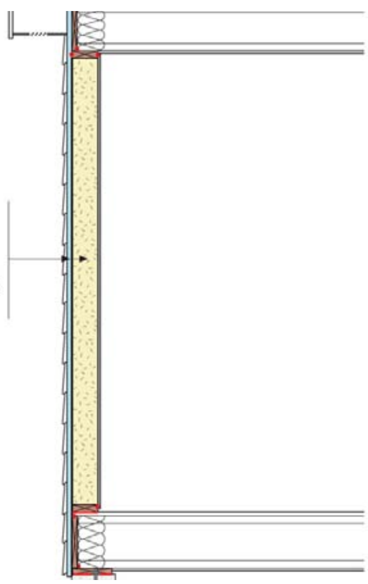
Thermal Control - Walls



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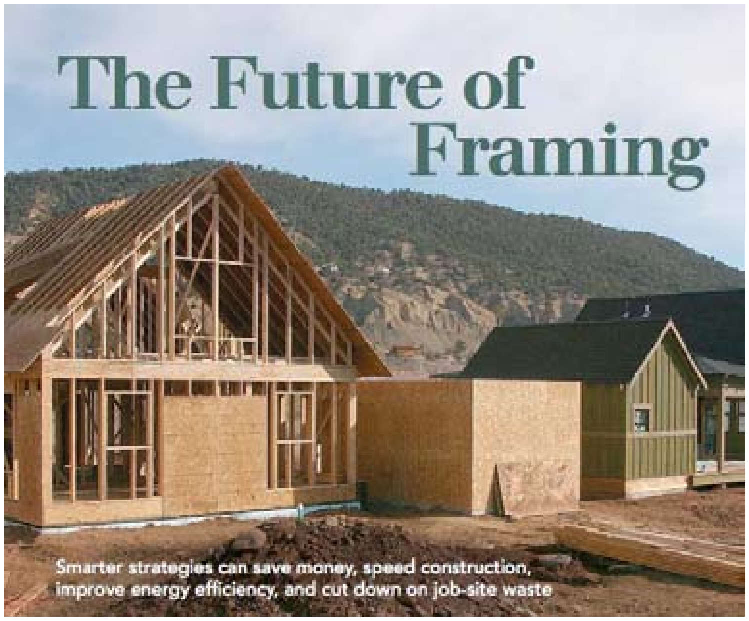
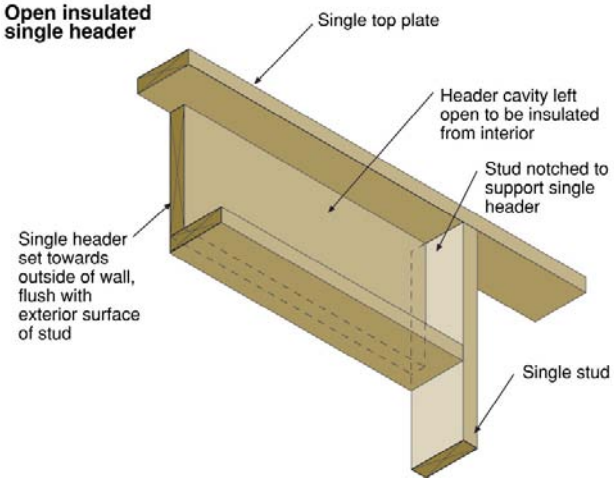

The Future of
Framing
Smarter strategies can save money, speed construction, improve energy efficiency, and cut down on job-site waste

2x6 Framing, 24" o.c.

Right-sized Headers



Reduce framing in non-bearing walls

63

Two-stud corners and Drywall clips

- Clips save wood, labor and call-backs
- NAHB: $100/1000 sq ft in material
- Further savings in energy . . .

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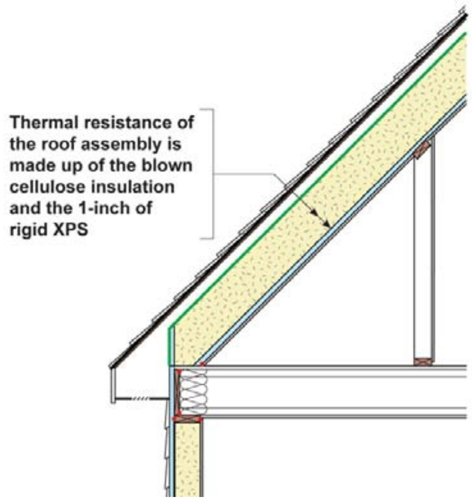
Thermal Control - Roofs



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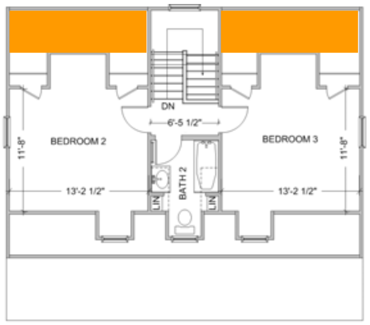
Pushing the Envelope . . .



Second Floor Plan

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Resources

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Resources

Building Science Corporation

Designs that Work – Mixed-Humid Climate Case Study

find this at:

www.buildingscience.com/dtw

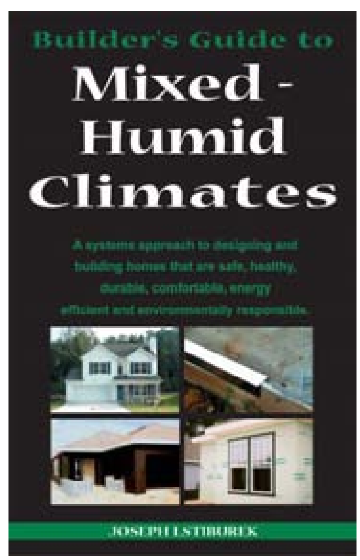
Resources

Building Science Corporation

Builder's Guide to Mixed-Humid Climates

find this at:

www.buildingsciencepress.com



Resources

Building America

Mixed-Humid Climate Best Practices Guide

find this at:

www.buildingamerica.gov

(look for "publications")

Rebuilding Greensburg

A Seminar Series on Affordable, Energy Efficient Construction Techniques

Building America U.S. Department of Energy Research Toward Zero Energy Homes

Part 1: House Design and Foundation Systems

Date: September 8, 2007

- An overview of energy efficient and affordable house design
- Foundations and rainwater management

Part 2: Framing

- Advanced framing techniques
- Choosing the right windows and doors

Part 3: Mechanical Systems and Airtightness

- Build tight, ventilate right
- Mechanical system design and selection

Part 4: Enclosure

- Insulation – theory and installation practices
- Exterior cladding systems

Part 5: Finishes, Testing and Commissioning

- Measuring building performance
- Whole house commissioning and homeowner training

Questions?

Before you go . . .

- **Sign up sheet for builders**

B.8 Building for Energy Efficiency – Part 4

Steve Bolibruck
IBACOS

IBACOS

Building for Energy Efficiency 4:

Alternative design approaches
for energy efficient homes

Steve Bolibruck

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Session Objectives

- Learn about different metrics and programs available to better quantify the savings message
- Discuss different specification packages that achieve different levels of energy efficiency
- Next steps

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Program Introductions

- There are several different energy savings programs and incentives out there but this session will focus on three:
  - Building America Program
  - HERS Index
  - Federal Tax Credit for Home Builders

IBACOS

Building America

- Building America is sponsored by the U.S. Department of Energy and conducts research to find energy efficient solutions for new and existing housing
- Throughout the design and construction process, research participants in Building America projects evaluate the interaction between the building site, envelope, mechanical systems, and energy-use factors
- The research conducted by Building America teams increases the quality and performance of today's homes and provides valuable information for homes of the future

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Building America

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- The long-term goal of the Building America program is to develop cost-effective systems for homes that can produce as much energy as they use – a zero energy home
- Whole house energy savings goals were established and mapped out – 30%, 40%, 50%...
- The reference used to determine the whole house energy savings of a project is the Building America Benchmark

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Building America Benchmark

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- Building America Benchmark defined:
  - Benchmark is generally consistent with mid-1990s standard practice
  - In addition to the tradition programs that focus on space conditioning and hot water, the Benchmark has additional definitions that allow the evaluation of all residential end-uses
  - All building envelope component references to U-values for the Benchmark have been updated to 2003 International Energy Conservation Code (2003 IECC)
  - Benchmark represents typical construction at a fixed point in time so it can be used as the basis for Building America's multi-year energy savings goals

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HERS Index

- The HERS Index is a scoring system established by the Residential Energy Services Network (RESNET)
- The HERS Reference Home is based on the 2006 International Energy Conservation Code
- The lower a home's HERS Index, the more energy efficient it is in comparison to the HERS Reference Home
- A house built with the same specifications as the Reference House would have a HERS Index of 100, while a net zero energy home has a HERS Index of 0
- Each 1-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption

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Federal Tax Credit

- Tax Credit for Home Builders:
  - Home builders are eligible for a $2,000 tax credit for a new energy efficient home
  - The house must achieve 50 percent energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC) and supplements. At least 1/5 (10%) of the energy savings must come from building envelope improvements
  - This credit also applies to contractors of manufactured homes conforming to Federal Manufactured Home Construction and Safety Standards

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Federal Tax Credit

- Additional Tax Credit for Manufactured Home Builders:
  - Producers of a new manufactured are eligible for a $1,000 tax credit
  - The house must achieve 30 percent energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC) and supplements. At least 1/3 (10%) of the energy savings must come from building envelope improvements
  - Manufactured homes meeting the requirements established by EPA under the ENERGY STAR program also qualify

30% Specification Package

Greensburg - Preliminary Specification Analysis

Two-Story w/ Unfinished Basement
2182 ft² conditioned floor area, 287 ft² window area

System Specifications

Component	30% Specification Package
Foundation System	R-10 Basement walls, conditioned basement
Above Grade Exterior Walls	2x6 framed walls with R-19 batt insulation
Overhanging Floors	R-30
Roof	R-40 vented attic
Exterior Doors	R-5
Windows	Low-E/Low SHGC (U=0.30;SHGC=0.37)
Building Air Tightness	ACH50 = 4
Mechanical Ventilation	Supply air to return duct with runtime and damper control, adjustable to meet ASHRAE 62.2 ventilation requirements
Heating	90% AFUE Natural Gas Furnace
Cooling	SEER 14 A/C Unit
Ductwork	Supply ducts located within conditioned space, return ducts and air handler located in conditioned basement, 5% leakage to exterior, R-8 duct insulation
Water Heater	Nat. gas, EF=0.61
Appliances	Electric range & dryer
Fluorescent Lighting	50% Fluorescent lighting
% Better than Building America Benchmark	**34.0%**
HERS Index 2006	**65**
Tax Credit Compliant	**Compliant (53% htg/clg - 40% envl)**

IBACOS

30% Cost Savings

Estimated Annual Cost Savings: 30% Savings Target

	Greensburg
Estimated Incremental First Cost Relative to Standard Practice[1]	$4,000
Annual Amortized Cost 7%, 30Year mortgage[2]	$211
Estimated Annual Utility Bill Savings	$723
Net Annual Savings	**$512**

(2000 ft2, 2-story, 16% window to floor area ratio, unconditioned basement)

[1] Evaluated relative to minimum IECC 2003.

[2] Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.

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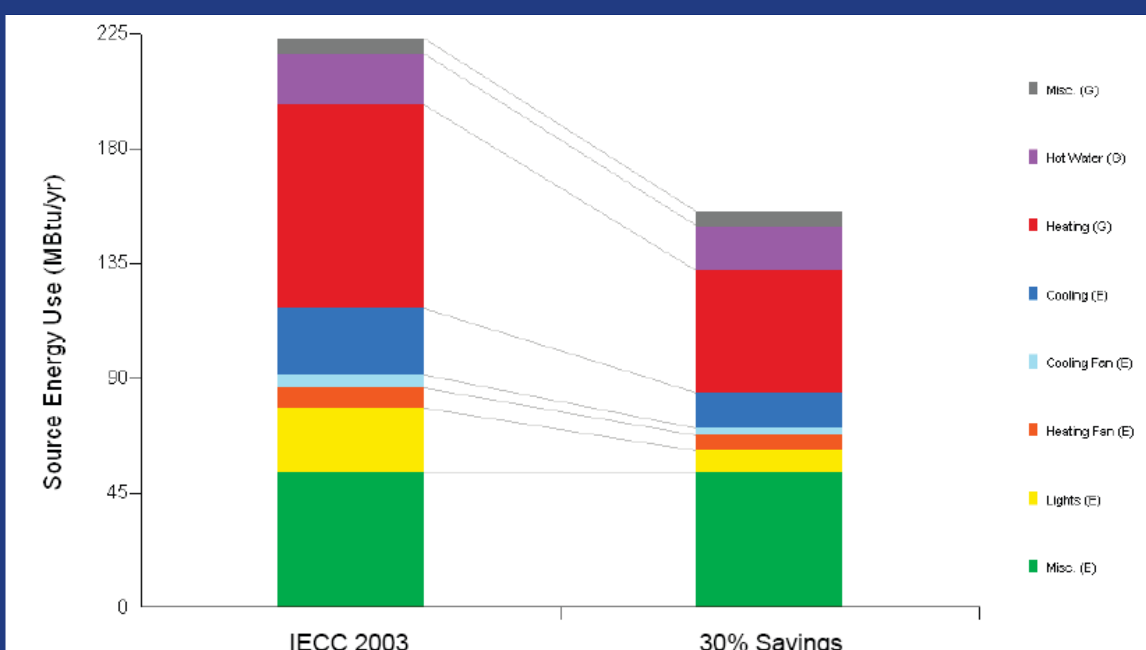
Estimated Annual Energy Savings by End Use – 30% Target



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40% Specification Packages

Greensburg - Preliminary Specification Analysis

Two-Story w/ Unfinished Basement
2182 ft² conditioned floor area, 287 ft² window area

System Specifications	
Component	**40% Specification Package**
Foundation System	R-10 Basement walls, conditioned basement
Above Grade Exterior Walls	2x6 framed walls with R-21 batt insulation
Overhanging Floors	R-30
Roof	R-50 vented attic
Exterior Doors	R-5
Windows	Low-E/Low SHGC (U=0.28;SHGC=0.37)
Building Air Tightness	ACH50 = 3
Mechanical Ventilation	Supply air to return duct with runtime and damper control, adjustable to meet ASHRAE 62.2 ventilation requirements
Heating	90% AFUE Natural Gas Furnace
Cooling	SEER 18 A/C Unit
Ductwork	Supply ducts located within conditioned space, return ducts and air handler located in conditioned basement, 2.5% leakage to exterior, R-8 duct insulation
Water Heater	Nat. gas, EF=0.61
Appliances	Electric range & dryer
Fluorescent Lighting	80% Fluorescent lighting
% Better than Building America Benchmark	**40.2%**
HERS Index 2006	**61**
Tax Credit Compliant	**Compliant (60% htg/clg - 45% envl)**

40% Cost Savings

Estimated Annual Costs: 40% Efficiency Target

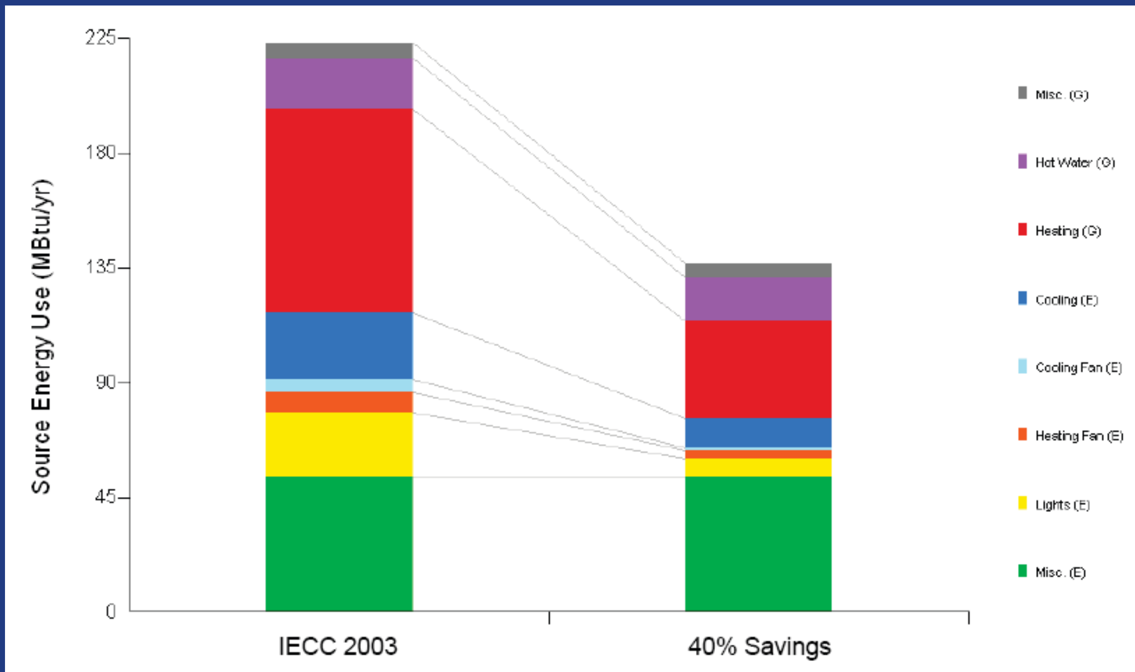
	Greensburg
Estimated Incremental First Cost Relative to Standard Practice[1,2]	$7,000
Annual Amortized Cost 7%, 30 Year mortgage[3]	$411
Annual Utility Bill Savings	$919
Net Annual Savings	**$508**

(2000 ft2, 2-story, 16% window to floor area ratio), unconditioned basement

1 Evaluated relative to minimum IECC 2003.
2 Qualifies for federal new home tax credit.
3 Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.

8

Estimated Annual Energy Savings by End Use – 40% Target



50% Specification Packages

Greensburg - Preliminary Specification Analysis

Two-Story w/ Unfinished Basement
2182 ft² conditioned floor area, 287 ft² window area

System Specifications	
Component	**50% Specification Package**
Foundation System	R-10 Basement walls, conditioned basement
Above Grade Exterior Walls	2x6 framed walls with R-22 batt insulation and foam sheathing
Overhanging Floors	R-30
Roof	R-50 vented attic
Exterior Doors	R-5
Windows	Low-E/Low SHGC (U=0.28;SHGC=0.37)
Building Air Tightness	ACH50 = 2
Mechanical Ventilation	Supply air to return duct with runtime and damper control, adjustable to meet ASHRAE 62.2 ventilation requirements
Heating	94% AFUE Natural Gas Furnace
Cooling	SEER 18 A/C Unit
Ductwork	Supply and return ducts and air handler located within conditioned space, 0% leakage to exterior
Water Heater	Nat. gas, Tankless EF=0.82
Appliances	Electric range & dryer, Energy Star appliances
Fluorescent Lighting	80% Fluorescent lighting
% Better than Building America Benchmark	**49.3%**
HERS Index 2006	**51**
Tax Credit Compliant	**Compliant (68% htg/clg - 50% envl)**

IBACOS

50% Cost Savings

Estimated Annual Costs: 50% Efficiency Target

	Greensburg
Estimated Incremental First Cost Relative to Standard Practice[1,2]	$13,000
Annual Amortized Cost 7%, 30Year mortgage[3]	$706
Annual Utility Bill Savings	$1162
Net Annual Savings	**$456**

(2000 ft2, 2-story, 16% window to floor area ratio), unconditioned basement

1 Evaluated relative to minimum IECC 2003.
2 Qualifies for federal new home tax credit.
3 Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.

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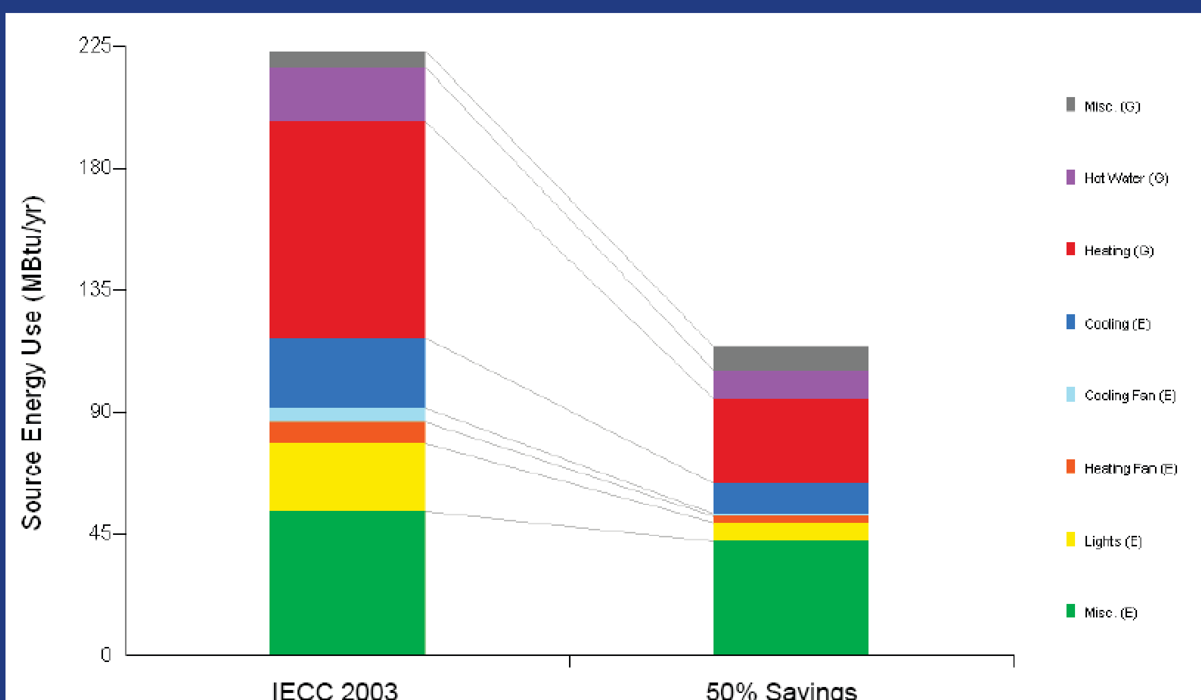
Estimated Annual Energy Savings by End Use – 50% Target



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Plan 1 Specification Packages

Greensburg - Plan 1 - Preliminary Specification Analysis

Two-Story w/ Unfinished Basement

System Specifications

Component	Optional Spec Package - Plan 1
Foundation System	R-5 1" XPS foam insulation on interior of basement walls
Above Grade Exterior Walls	2x6 wood framed 24" o/c (advanced framing) with R-19 damp-spray cellulose cavity insulation and R-5 XPS insulating foam sheathing
Overhanging Floors	N/A
Roof	R-38 cellulose insulation on flat ceilings; R-30 cellulose insulation & R-5 XPS foam sheathing on cathedral ceilings
Exterior Doors	R-7
Windows	High performance, Low-E, double paned, vinyl windows (U=0.32;SHGC=0.32)
Building Air Tightness	ACH50 = 3.4
Mechanical Ventilation	Supply-only system with fan cycling controller and motorized damper, integrated with air handling unit, supply rate @ 55 CFM for 33% run-time
Heating	Natural Gas Furnace, 92.1% AFUE
Cooling	None
Ductwork	Supply and return ducts and air handler located within conditioned space, 0% leakage to exterior
Water Heater	Natural Gas, EF = 0.62
Appliances	Electric dryer & range, Energy Star Appliances
Fluorescent Lighting	100% Fluorescent Lighting
% Better than Building America Benchmark	**33.4%**
HERS Index 2006	**73**
Tax Credit Compliant	**Non-compliant (46% htg/clg - 37% envl)**

REBUILDING GREENSBURG...
as a healthy, energy efficient, affordable town

Upcoming this fall . . .

Rebuilding Greensburg:
A Seminar Series on Affordable, Energy Efficient Construction Techniques

The U S Department of Energy's Building America program will be offering a special, five-part training series for builders and homeowners involved in rebuilding Greensburg as a healthy, energy efficient and affordable town.

Each seminar will include a 1/2-day tour of current re-construction projects in Greensburg where participants will learn about and examine best practice construction methods. The field visit will be followed by a 1/2-day in-class training session lead by residential construction experts from Building America project teams.

Part 1: House Design and Foundation Systems
- Date: September 8, 2007
- Location: TBD
- Topics will include:
  - An overview of energy efficient and affordable house design
  - Foundations and rainwater management

Part 2: Framing
- Date: to be announced
- Topics will include:
  - Advanced framing techniques
  - Choosing the right windows and doors

Part 3: Mechanical Systems and Airtightness
- Topics will include:
- Date: to be announced
  - Build tight, Ventilate right
  - Mechanical system design and selection

Part 4: Enclosure
- Topics will include:
- Date: to be announced
  - Insulation - theory and installation practices
  - Exterior cladding systems

Part 5: Finishes, Testing and Commissioning
- Topics will include:
- Date: to be announced
  - Measuring building performance
  - Whole house commissioning and homeowner training

For more information about the seminar series and early registration, please contact betsy@buildingscience.com

The U.S. Department of Energy's Building America Program is reengineering the American home for energy efficiency and affordability. Building America works with the residential building industry to develop and implement innovative building processes and technologies – innovations that save builders and homeowners millions of dollars in construction and energy costs. This industry-led, cost-shared partnership program uses a systems engineering approach to reduce energy use, utility bills, construction time, and construction waste.

For more information, visit our website at: www.buildingamerica.gov

B.9 Plan 1 - Three Bedroom, Basement, Greensburg, Kansas

Building Science Corporation

Greensburg, KS

PLAN 1 - THREE BEDROOM - BASEMENT

PROJECT DESCRIPTION

These plans describe an affordable, energy-efficient, and durable 1350 sq ft single-family home. The drawing set and specifications were developed by Building Science Corporation through the Department of Energy's Building America Program for the Building Greensburg Builder Workshop Series. The plans provide an example of how homes in Greensburg could be rebuilt as part of a healthy, energy efficient and affordable town. During project planning and construction, all efforts should be made to meet the goals of this project.

SQUARE FOOTAGES

BASEMENT	816 SQ FT
FIRST FLOOR	840 SQ FT
SECOND FLOOR	528 SQ FT

Notes: 1. Area calculations according to ANSI Z765-2003.
2. Finished square footage calculations for this house were made based on plan dimensions only and may vary from the finished square footage of the house as built.

DRAWING LIST

DATE: 19 OCTOBER 2007

BUILDING SCIENCE CORPORATION
70 MAIN STREET WESTFORD, MASSACHUSETTS 01886
P: 978-589-5100 F: 978-589-5103

GENERAL REQUIREMENTS

1. ALL WORK SHALL COMPLY WITH FEDERAL, STATE AND LOCAL BUILDING CODES AND REGULATIONS.

2. MECHANICAL, ELECTRICAL AND PLUMBING WORK REQUIRED OF THIS PERMIT APPLICATION TO BE PERFORMED BY SUBCONTRACTOR LICENSED IN THE STATE IN WHICH WORK IS BEING PERFORMED.

3. SUBCONTRACTOR SHALL PROVIDE CERTIFICATION OF GENERAL LIABILITY INSURANCE AND WORKMAN'S COMPENSATION COVERAGE, AS REQUIRED BY THE GENERAL CONTRACTOR.

4. CONTRACTOR SHALL COORDINATE AND OBTAIN ALL BUILDING PERMITS REQUIRED FOR CONSTRUCTION AND CERTIFICATES OF OCCUPANCY.

5. CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR ALL CONSTRUCTION MEANS, METHODS, TECHNIQUES, AND PROCEDURES.

6. CONTRACTOR SHALL BE RESPONSIBLE FOR ALL ASPECTS OF SAFETY DURING BUILDING CONSTRUCTION AND SHALL PROVIDE ADEQUATE SHORING AND BRACING TO ENSURE SUCH SAFETY.

7. ALL DIMENSIONS AND SITE CONDITIONS TO BE FIELD VERIFIED AND SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR. NOTIFY BUILDING SCIENCE CORPORATION OF AN DISCREPANCY PRIOR TO COMMENCEMENT OF WORK.

8. IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO LOCATE ALL EXISTING UTILITIES WHETHER INDICATED ON PLANS OR NOT, AND TO PROTECT THEM FROM DAMAGE.

9. ALL DETAILS, SECTIONS, NOTES, OR REFERENCE TO OTHER DRAWINGS ARE INTENDED TO BE TYPICAL.

10. DURING CONSTRUCTION, AND PRIOR TO THE INCORPORATION OF ANY CHANGES, REVISIONS, MODIFICATIONS AND/OR DEVIATIONS FROM THE CONSTRUCTION DOCUMENTS, CONTRACTOR SHALL BRING TO THE ATTENTION OF BUILDING SCIENCE CORPORATION AND OBTAIN APPROVAL FROM THE GOVERNING BUILDING OFFICIAL BEFORE PROCEEDING WITH THE WORK.

11. THE MANUFACTURERS, PRODUCTS AND EQUIPMENT LISTED ESTABLISH PERFORMANCE REQUIREMENTS. SUBSTITUTIONS OF EQUAL PERFORMANCE MAY BE SUBMITTED FOR BUILDING SCIENCE CORPORATION'S APPROVAL.

12. ALL MATERIALS SHALL BE INSTALLED PER MANUFACTURER'S INSTRUCTIONS/SPECIFICATIONS UNLESS OTHERWISE SPECIFIED BY BUILDING SCIENCE CORPORATION.

13. SPECIFIC NOTES AND DETAILS ON DRAWINGS SHALL TAKE PRECEDENCE OVER GENERAL NOTES AND TYPICAL DETAILS. WHERE NO DETAILS ARE SHOWN, CONSTRUCTION SHALL CONFORM TO SIMILAR WORK ON THE PROJECT.

BUILDING AMERICA PERFORMANCE CRITERIA

REQUIREMENTS: DESIGN

RESIDENCES MUST REDUCE WHOLE HOUSE ENERGY USE (HVAC, HOT WATER, LIGHTING, AND ALL APPLIANCES/PLUG LOADS) AS STIPULATED IN THE TABLE BELOW:

PROJECT TYPE	PERCENT REDUCTION	ENERGY STAR INDEX
SINGLE HOMES	40%	60–65
COMMUNITIES	30%	70–75

WHOLE-HOUSE DILUTION VENTILATION: A MECHANICAL VENTILATION SYSTEM MUST BE INSTALLED TO BE CAPABLE OF MEETING ASHRAE STANDARD 62.2 WHICH STIPULATES A VENTILATION RATE OF 7.5 CFM PER PERSON (COUNTED AS THE NUMBER OF BEDROOMS PLUS ONE) PLUS 0.01 CFM PER SQUARE FOOT OF FLOOR AREA. WHILE 62.2 STIPULATES THAT OPERATION OF THE VENTILATION SYSTEM IS AT THE OCCUPANT'S DISCRETION AND THE STANDARD IS SILENT REGARDING WHOLE HOUSE DISTRIBUTION OF VENTILATION AIR, THIS PERFORMANCE CRITERIA STIPULATES THAT THE 62.2 VENTILATION FLOW RATE BE DELIVERED AT LEAST ONE-THIRD OF THE TIME AND THAT WHOLE HOUSE DISTRIBUTION IS REQUIRED.

LOCAL EXHAUST VENTILATION: INTERMITTENT SPOT EXHAUST OF 100 CFM MUST BE PROVIDED FOR EACH KITCHEN (RECIRCULATING COOKTOP HOODS ARE NOT PERMITTED). INTERMITTENT SPOT EXHAUST OF 50 CFM OR CONTINUOUS EXHAUST OF 20 CFM WHEN THE BUILDING IS OCCUPIED MUST BE PROVIDED FOR EACH ROOM HAVING A TOILET, BATH, OR SHOWER.

VENTILATION INTAKE LOCATIONS: WHEN A SUPPLY-ONLY OR BALANCED VENTILATION SYSTEM IS USED, THE INTAKE MUST GO THROUGH AN OUTSIDE WALL AND NOT THE ROOF (DUE TO PROXIMITY TO EXHAUST/VENT POLLUTANTS, AND HEATED AIR/VOC'S/ODORS FROM THE ROOF). WALL INTAKES SHOULD BE LOCATED AT LEAST 10 FEET FROM, AND NOT DIRECTLY ABOVE, ANY WALL EXHAUST OR VENT.

ALL COMBUSTION APPLIANCES (EXCEPT A GAS STOVE, COOKTOP OR OVEN) IN THE CONDITIONED SPACE MUST BE SEALED COMBUSTION. SPECIFICALLY, ANY FURNACE INSIDE CONDITIONED SPACE MUST BE A SEALED-COMBUSTION 90%+ AFUE UNIT. ANY WATER HEATER INSIDE CONDITIONED SPACE MUST BE DIRECT-POWER-VENTED. ANY BOILER INSIDE A CONDITIONED SPACE MUST BE SEALED COMBUSTION.

WINDOWS WITH THE FOLLOWING CLIMATE-SPECIFIC PERFORMANCE VALUES MUST BE USED:

CLIMATE ZONE	MAXIMUM U-VALUE	MAXIMUM SHGC
ZONES 1–3	0.40	0.35
ZONES 4–8	0.35	0.40

ALL DUCTS AND AIR HANDLING EQUIPMENT MUST BE IN THE CONDITIONED SPACE.

MAJOR APPLIANCES (REFRIGERATOR, CLOTHES WASHER, AND DISHWASHER) MUST ACHIEVE ENERGY STAR PERFORMANCE IN THE TOP ONE-THIRD OF THE DOE ENERGY GUIDE RATING SCALE.

ALL LIGHTING MUST BE ENERGY STAR QUALIFIED WITH THE FOLLOWING EXCEPTIONS: MOTION-SENSITIVE OUTDOOR SPOTLIGHTS AND SOLAR-POWERED ACCENT AND PATHWAY LIGHTING. LED TECHNOLOGY IS CURRENTLY NOT CERTIFIED BY ENERGY STAR. HOWEVER, LEDS ARE ACCEPTABLE.

CARBON MONOXIDE DETECTORS (HARD WIRED UNITS) MUST BE INSTALLED (AT ONE PER EVERY APPROXIMATE 1000 SQUARE FEET) IN ANY HOUSE CONTAINING COMBUSTION APPLIANCES OR AN ATTACHED GARAGE.

REQUIREMENTS: TESTING

BUILDING AMERICA TESTING OF THE HOUSE MUST BE COMPLETED AS PART OF THE COMMISSIONING PROCESS.

IN A PRODUCTION SETTING, EACH MODEL TYPE (i.e., FLOOR PLAN) MUST BE TESTED UNTIL TWO CONSECUTIVE HOUSES OF THIS MODEL TYPE MEET TESTING REQUIREMENTS. ADDITIONALLY, TESTING OF THIS MODEL TYPE CAN BE REDUCED TO A SAMPLING RATE OF 1 IN 7 (i.e., 1 TEST, WITH 6 "REFERENCED" HOUSES). SMALL ADDITIONS TO A FLOOR PLAN (e.g., BAY WINDOW, CONVERSION OF DEN TO BEDROOM) ARE CONSIDERED TO BE THE SAME MODEL TYPE; MAJOR CHANGES (e.g., BONUS ROOM OVER THE GARAGE, CONVERSION OF GARAGE INTO A HOBBY ROOM, ETC.) MUST BE CONSIDERED A SEPARATE MODEL TYPE. UNIQUE OR CUSTOM HOUSE PLANS MUST BE INDIVIDUALLY TESTED.

AIR LEAKAGE (DETERMINED BY PRESSURIZATION TESTING) MUST BE LESS THAN 2.5 SQUARE INCHES/100 SQUARE FEET SURFACE AREA LEAKAGE RATIO (CGSB, CALCULATED AT A 10 PA PRESSURE DIFFERENTIAL); OR 1.25 SQUARE INCHES/100 SQUARE FEET LEAKAGE RATIO (ASTM, CALCULATED AT A 4 PA PRESSURE DIFFERENTIAL); OR 0.25 CFM/SQUARE FOOT OF BUILDING ENCLOSURE SURFACE AREA AT A 50 PASCAL AIR PRESSURE DIFFERENTIAL. THE CALCULATION OF THE BUILDING ENCLOSURE AREA INCLUDES THE FOUNDATION OR BELOW GRADE SURFACE AREAS. IF THE HOUSE IS DIVIDED INTO MULTIPLE CONDITIONED ZONES, SUCH AS CONDITIONED ATTICS OR CONDITIONED CRAWL SPACE, THE BLOWER DOOR REQUIREMENT MUST BE MET WITH THE ACCESS TO THE SPACE OPEN, CONNECTING THE ZONES.

TOTAL SPACE CONDITIONING SYSTEM DUCT LEAKAGE MUST BE LESS THAN FIVE PERCENT OF THE TOTAL AIR HANDLING SYSTEM RATED AIR FLOW AT HIGH SPEED (NOMINAL 400 CFM PER TON) DETERMINED BY PRESSURIZATION TESTING AT 25 PA. TWO COMPLIANCE MECHANISMS ARE ACCEPTABLE: (1) TEST TOTAL DUCT LEAKAGE AT FINISH STAGE, OR (2) TEST TOTAL DUCT LEAKAGE AT DUCT ROUGH-IN STAGE. WHEN MORE THAN ONE AIR HANDLER EXISTS, EACH AIR HANDLING SYSTEM MUST INDIVIDUALLY MEET THE REQUIREMENT. IF ZONING IS USED, ALL ZONE DAMPERS MUST BE OPEN. MANUAL OR MOTORIZED OUTSIDE AIR VENTILATION DAMPERS MUST BE CLOSED.

LOCAL AND WHOLE-HOUSE MECHANICAL VENTILATION SYSTEM AIRFLOWS MUST BE TESTED DURING COMMISSIONING OF THE BUILDING.

FORCED AIR SYSTEMS THAT DISTRIBUTE AIR FOR HEATING MUST BE DESIGNED TO PROVIDE BALANCED AIRFLOW TO ALL CONDITIONED SPACES AND ZONES (BEDROOMS, HALLWAYS, BASEMENTS). BALANCED AIRFLOW IS DEFINED AS A SYSTEM THAT CONTROLS INTER-ZONAL AIR PRESSURE DIFFERENCES WHEN DOORS ARE CLOSED TO LESS THAN 3 PA USING PASSIVE TRANSFER GRILLES, JUMP DUCTS, DOOR UNDERCUTS OR ACTIVE RETURN DUCTS OR ANY COMBINATION THEREOF.

SYSTEM EXTERNAL STATIC PRESSURE MUST BE WITHIN MANUFACTURERS SPECIFICATIONS (0.5 WIC/125 PA MAXIMUM TYPICAL).

GENERAL CONSTRUCTION NOTES

CIVIL NOTES:

DEBRIS – REMOVE DEBRIS WITHIN 2'-0" OF BUILDING.

EXTERIOR GRADE – SLOPE GRADE 5% TO DRAIN AWAY FROM BUILDING.

SOIL GAS CONTROL – ALL WALLS, ROOF AND FLOORS IN CONTACT WITH THE GROUND SHALL BE CONSTRUCTED TO RESIST THE LEAKAGE OF SOIL GAS FROM THE GROUND TO THE BUILDING. A PASSIVE SUB-SLAB DEPRESSURIZATION SYSTEM IN ACCORDANCE WITH THE SUPPLEMENTARY GUIDELINES SHALL BE PROVIDED, 1 VENT PIPE, MIN. 3" DIAMETER, PER 1500 SF OF SLAB AREA. VENT STRAIGHT UP THRU ROOF.

STRUCTURAL NOTES:

CONCRETE – ALL CONCRETE TO HAVE A WATER/CEMENT RATIO OF LESS THAN 0.5 AND 10% FLY ASH PORTLAND CEMENT REPLACEMENT.

FOOTINGS – ALL FOOTINGS SHALL REST ON NATIVE, UNDISTURBED SOIL AND WILL BE A MIN. OF 48" BELOW FINISHED GRADE OR IN ACCORDANCE WITH LOCAL BUILDING CODE. APPLY LIQUID APPLIED CAPILLARY BREAK (MUST DRY TACK FREE) ON TOP OF FOOTING PRIOR TO PLACING/CASTING CONCRETE FOUNDATION WALL.

STEP FOOTINGS – HORIZONTAL STEP = 24" MAX.
– VERTICAL STEP = 24" MAX.

FOUNDATION WALLS – 8" WIDE CONCRETE WALL WITH 2 1/2" DEEP VERTICAL SAW-CUT CONTROL JOINTS ON INTERIOR FACE OF WALL. LOCATE JOINTS 18" FROM EVERY CORNER AND 20' MAX. ALONG LENGTH OF WALL SEGMENT.

DRAIN TILE – 4" DIA. PIPE, 3/4" CRUSHED STONE (NO FINES), 6" MIN. PIPE COVER. LOCATE 4" DIA. DRAIN TILE CONNECTION PIPE THROUGH BASE OF FOOTING WITHIN 5' OF EVERY CORNER AND EVERY 15' MAX. ALONG LENGTH OF WALL SEGMENT WITH MIN. 1 PER WALL SEGMENT.

~~CRAWLSPACE FLOOR – 6 mil POLYETHYLENE SHEET ON 6" CLEAN CRUSHED STONE PAD.~~

~~CRAWLSPACE WALL – 8", 2200 P.S.I. POURED CONCRETE W/ BITUMINOUS DAMPPROOFING.~~
~~– FILL AND SEAL ALL TIE HOLES.~~
~~– TOP OF FOUNDATION WALL TO BE 8" MIN. ABOVE FINISHED GRADE.~~

SILL PLATE – 2x6 TREATED SILL PLATE WITH 1/2" DIA. ANCHOR BOLTS 12" LONG, SET MIN. 4" INTO CONCRETE AND SPACED AT 6' O.C MAX. PROVIDE CAPILLARY BREAK BETWEEN SILL PLATE AND CONCRETE, 6 mil POLY OR EQUAL.

ANCHOR BOLTS – PROVIDE 1/2" DIA. ANCHOR BOLTS 12" LONG, SET MIN. 4" INTO CONCRETE SPACED AT 6' O.C. MAX. TWO BOLTS MIN. PER PLATE SECTION WITH ONE BOLT LOCATED NOT MORE THAN 12" OR LESS THAN SEVEN BOLT DIAMETERS FROM EACH END OF THE PLATE SECTION.

BEARING STUD PARTITION – 2x6 STUDS AT 24" O.C.

STEEL COLUMN – 3" DIA. HSS ON 3'-0" x 3'-0" x 12" CONCRETE PAD W/ (4) #5 REBAR EACH WAY.

CONCRETE SLAB – 4" CONCRETE SLAB WITH SAW-CUT CONTROL JOINTS SPACED AT 20' MAX. AND SAW-CUT COLUMN ISOLATION JOINTS.

~~PORCH SLAB – 4" CONC. SLAB – 4650 P.S.I. @ 28 DAYS, 5-8% AIR ENTRAINMENT ON COMPACTED CRUSHED STONE. SLOPE SLAB 1" MIN. AWAY FROM HOUSE.~~

~~GARAGE SLAB – 4" CONC. SLAB ON COMPACTED CRUSHED STONE WITH FIBERMESH REINFORCING – 4650 P.S.I. @ 28 DAYS, 5-8% AIR ENTRAINMENT, SLOPE SLAB 3" MIN TO FRONT.~~

BEAMS AND LINTELS – SUPPORT FULL WIDTH TO FOUNDATION.

ARCHITECTURAL NOTES:

~~EAVESTROUGH – ALUMINUM EAVESTROUGH ON 2x6 WOOD FASCIA BOARD.~~

DRIP EDGE – PROVIDE 1" DRIP EDGE ON FLASHING OVER OPENINGS IN EXTERIOR WALLS.

~~ATTIC ACCESS – OPENING 20" x 28" MIN. WITH WEATHERSTRIPPING AND INSULATION.~~

WOOD PROTECTION – WOOD FRAMING MEMBERS THAT ARE NOT PRESSURE TREATED WITH A WOOD PRESERVATIVE AND WHICH ARE SUPPORTED ON CONCRETE IN CONTACT WITH THE GROUND SHALL BE SEPARATED FROM THE CONCRETE BY AT LEAST 6 mil POLY FILM OR EQUAL.

STAIR DIMENSIONS (ALL INTERIOR AND EXTERIOR STAIRS)
MIN. RISE – 5"
MAX. RISE – 7 3/4"
MIN. RUN – 8 1/4"
MAX. RUN – 1'-1 7/8"
MIN. TREAD – 10"
MAX. TREAD – 1'-1 7/8"
MAX. NOSING – 1"
MIN. HEADROOM – 6'-5"
MIN. WIDTH – 2'-10"

HANDRAILS AND GUARDS
– MIN. HEIGHT – 2'-11"
– A CLEARANCE OF NOT LESS THAN 2" SHALL BE PROVIDED BETWEEN HANDRAIL AND ANY SURFACE BEHIND IT.

BEDROOM EGRESS – MIN. ONE WINDOW PER BEDROOM LEVEL SHALL PROVIDE AN INDIVIDUAL UNOBSTRUCTED OPEN PORTION HAVING A MIN. AREA OF 3.8 sq. ft. AND HAVING NO DIMENSION LESS THAN 1'-3" (NOT APPLICABLE IF THERE IS A DOOR W/ DIRECT ACCESS TO THE EXTERIOR ON THAT LEVEL).

INTERIOR DOORS – UNDERCUT ALL DOORS 3/4" MIN.

COAT CLOSETS – (1) ROD AND (1) SHELF MIN.

LINEN CLOSETS – (4) SHELVES MIN. AND 1'-2" DEEP MIN.

MINIMUM HEADROOM – 6'-5" BELOW ALL BEAMS AND DUCTS.

MECHANICAL, ELECTRICAL, AND PLUMBING NOTES:

EXHAUST FANS – VENT TO EXTERIOR.

RANGE HOODS – VENT TO EXTERIOR W/ NON-COMBUSTABLE DUCT.

DRYER VENT – CAPPED AND SCREENED DRYER VENT, DUCTING INSTALLED TO SLOPE TO EXTERIOR.

SMOKE DETECTORS – LOCATE ON EACH FLOOR LEVEL AND INTERCONNECT.

CONSTRUCTION ASSEMBLIES

CONSTRUCTION SHALL CONFORM TO BUILDING AMERICA SPECIFICATIONS (UNITED STATES DEPARTMENT OF ENERGY) AND ASSEMBLIES AS LISTED BELOW:

FOUNDATION WALLS – FOUNDATION WILL BE A CONDITIONED BASEMENT. BASEMENT WALLS WILL BE CAST-IN-PLACE CONCRETE W/ 2" RIGID FOIL-FACED POLYISOCYANURATE INSULATION (R-13) RATED TO BE EXPOSED FOR FLAME SPREAD AND SMOKE DEVELOPED.

BASEMENT FLOOR SLAB – 4" CONCRETE SLAB OVER 6 MIL POLYETHYLENE VAPOR BARRIER OVER 6" CLEAN CRUSHED STONE PAD ON UNDISTURBED / NATIVE SOIL.

FRAME WALL CONSTRUCTION – EXTERIOR WALLS SHALL BE FRAMED WITH 2X6 STUDS AT 24" O.C.. CAVITY SHALL BE INSULATED WITH CELLULOSE TO R-19 (R-19 UNFACED FIBERGLASS BATT IS A SUITABLE SUBSTITUTION). EXTERIOR WALLS SHALL BE SHEATHED WITH ONE (1) 1 1/2" LAYER XPS RIGID INSULATION (R-7.5). 1/2" OSB OR PLYWOOD AND 1" XPS RIGID INSULATION SHALL BE INSTALLED AT THE CORNERS. USE DOW WEATHERMATE FLASHING TAPE AT HORIZONTAL JOINTS AND CORNERS (EXTERIOR AND INTERIOR), AT EXTERIOR FACE OF INSULATING SHEATHING AND DOW WEATHERMATE CONSTRUCTION TAPE AT VERTICAL JOINTS AT EXTERIOR FACE OF INSULATING SHEATHING.

ROOF CONSTRUCTION – ROOF SHALL BE FRAMED WITH 2X12 ROOF RAFTERS. RAFTERS SHALL BE INSULATED WITH CELLULOSE TO R-30 (R-30 FIBERGLASS BATT IS A SUITABLE SUBSTITUTION). ONE (1) 1" LAYER XPS (R-5) TO BE INSTALLED CONTINUOUSLY WITH ALL JOINTS TAPED WITH DOW WEATHERMATE CONSTRUCTION TAPE BELOW THE ROOF RAFTERS. GWB TO BE INSTALLED CONTINUOUSLY BELOW INSULATION.

INTERIOR NON-LOAD BEARING PARTITION CONSTRUCTION – 2X4 STUDS AT 24" O.C. WITH ONE (1) LAYER 1/2" GWB EACH SIDE.

TYP. FLOOR CONSTRUCTION – 7/8" T&G OSB SUBFLOOR ON TOP OF 9 1/2" DEEP ENGINEERED FLOOR JOIST WITH ONE (1) LAYER 1/2" GWB BELOW JOIST.

DOOR SPECIFICATION

A. EXTERIOR ENTRY DOORS:
1. INSULATED STEEL AND WEATHERSTRIPPED
2. OPEN FROM INSIDE WITHOUT KEY
3. PROVIDE VIEWER UNLESS TRANSPARENT GLASS IS PROVIDED IN DOOR OR SIDELITE

B. INTERIOR DOORS:
1. HOLLOW CORE

DOOR SCHEDULE

SIZE	TYPE	QUANTITY
3068	EXTERIOR	2
2868	EXTERIOR	1
2668	INTERIOR	8
2068	INTERIOR LOUVERED	9

WINDOW SPECIFICATION

ALL WINDOWS SHALL BE SPECTRALLY SELECTIVE LOW-E DOUBLE GLAZED VINYL FRAMED WITH THE FOLLOWING PERFORMANCE VALUES FROM THE NATIONAL FENESTRATION RATING COUNCIL (NFRC):

CLIMATE ZONE 4:
U-VALUE = 0.35 OR LESS
SOLAR HEAT GAIN COEFFICIENT (SHGC) = 0.40 OR LESS

1. CONFIRM R.O. SIZES WITH WINDOW MANUFACTURER AND ADJUST WALL FRAMING ACCORDINGLY.

2. SEE 4/A-13 FOR WINDOW INSTALLATION DETAILS.

3. 3050 SINGLE HUNG WINDOW MUST MEET IRC R310 REQUIREMENTS FOR EMERGENCY ESCAPE AND RESCUE OPENINGS.

WINDOW SCHEDULE

SIZE	TYPE	QUANTITY
3030	SINGLE HUNG	4
3050	SINGLE HUNG	11
4040	SLIDING	2

PRODUCT SPECIFICATION

	Product Type	Specified Product
A	Adhesive	
	Construction Adhesive	Polyseamseal All Purpose Adhesive Caulk, PL 200® Construction Adhesive or Equal
	Foam-Compatible Construction Adhesive	Liquid Nails Foamboard & Projects Adhesive (LN-604), PL 300® Foam Board Adhesive or Equal
	Attic Rafter Vent	TuffVENT, Owens Corning Raft-R-Mate or Equal
B	Backer Board	
	Cement Backer Board	USG Durock, WonderBoard Cement Backerboard or Equal
	Fiber Cement Backer Board	James Hardie HardieBacker Cement Board or Equal
C	Capillary Break (Footing-Liquid Applied)	W.R. Meadows SEALMASTIC Emulsion-Type or Solvent-Type Dampproofing or Equal
	Capillary Break (Sill)	
	Polyethylene	6 mil Polyethylene or Equal
	Foam	Dow Styrofoam Sill Seal, Owens Corning FoamSealR or Equal
	Cellulose Insulation (Borate-Treated Product Only)	
	Damp Sprayed	US GreenFiber INS735 Cocoon2 Stabilized Borate Formula-30 lbs. or Equal
	Loose Blown	US GreenFiber INS735 Cocoon2 Stabilized Borate Formula-30 lbs. or Equal
	Cladding Vent	Cor-A-Vent Siding Vent SV-3/5 or Equal
D	Dampproofing (Liquid Applied Bituminous)	W.R. Meadows SEALMASTIC Emulsion-Type or Solvent-Type Dampproofing or Equal
E	Expanding Polyurethane Foam Sealant	
	High Expansion	Dow Great Stuff Big Gap Filler or Equal
	Low Expansion	Dow Great Stuff Window & Door or Equal
	Extruded Polystyrene Foam (XPS)	Dow Styrofoam or Owens Corning Foamular
F	Filter Fabric	DuPont Landscape PRO Professional Grade Landscape Fabric or Equal
	Flashing	
	Metal Flashing	York Manufacturing Soleil® Copper-Aluminum Flashing or Equal
	Pre-Manufactured Sill Pan Flashing	Dow Weathermate Sill Pan or Equal
	Self Adhered Flashing	
	Formable Flashing	DuPont FlexWrap, Dow Weathermate Flexible Flashing or Equal
	Straight Flashing	W.R. Grace Vycor Plus, DuPont StraightFlash, Dow Weathermate Straight Flashing or Equal
	Fiberglass Insulation	
	Batts	Owens Corning PINK FIBERGLAS® Unfaced, Johns Manville Formaldehyde-free™batts Unfaced, Certainteed High-Performance Batts Unfaced
	Loose Fill	Owens Corning PINK FIBERGLAS®, Johns Manville Formaldehyde-free™ Climate Pro®/Attic Protector®, Certainteed InsulSafe® or Equal
	Foundation Drainage Mat	Cosella-Dorken Delta-MS, System Platon or Equal
	Fully-Adhered Waterproofing Membrane	W.R. Grace Ice and Water Shield or Equal
G	Gypsum Wall Board (GWB)	
	Paper Faced Gypsum Wall Board (GWB)	Sheetrock Brand Gypsum Panels or Equal
	Paperless Gypsum Wall Board (PGWB)	Georgia Pacific DensArmor Plus
H	Housewrap (Non-Micro Perforated Plastic)	
	Draining Housewrap	DuPont Tyvek Drainwrap
	Housewrap	DuPont Tyvek Homewrap, Fiberweb Typar HouseWrap, Dow Weathermate Plus, Johns Manville Gorilla Wrap, Fortifiber WeatherSmart
K	Kick-Out Diverter	Berger Kick-Out Diverter or Equal
R	Ridge Vent	Cor-A-Vent X-5 Extreme Ridge Vent, Trim Line Ridge Vents or Equal
	Rigid Polyisocyanurate	
	Foil Faced	Dow Tuff-R or Thermax
	Glass Fiber Faced	Dow Quik-R or Equal
S	Sealant	
	Air-Barrier Sealant	Tremco Acoustical Sealant or Equal
	Paintable Sealant	Polyseamseal All Purpose Adhesive Caulk, Sashco Sealants Big Stretch, Geocel ProCOLOR™ Tripolymer Sealant or Equal
	Urethane Sealant	Bostik Chem-Calk 955-SL Polyurethane Sealant or Equal
	Spray Polyurethane Foam	
	Closed Cell Spray Foam	Demilec Heatlok 2lbs/cubic foot or Equal
	Open Cell Spray Foam	Icynene 0.5 lbs/cubic foot or Equal
T	Tape	
	Builder's Sheathing Tape	Tyvek Tape, Dow Weathermate Construction Tape, 3M Contractor's Tape or Equal
	Foil Tape	3M Aluminum Foil Tape 1449 or Equal
	Thin Profile Sheathing	Thermoply or Equal

ARCHITECT:
BUILDING SCIENCE CORPORATION
70 MAIN STREET WESTFORD, MASSACHUSETTS 01886 PH: 978-589-5100

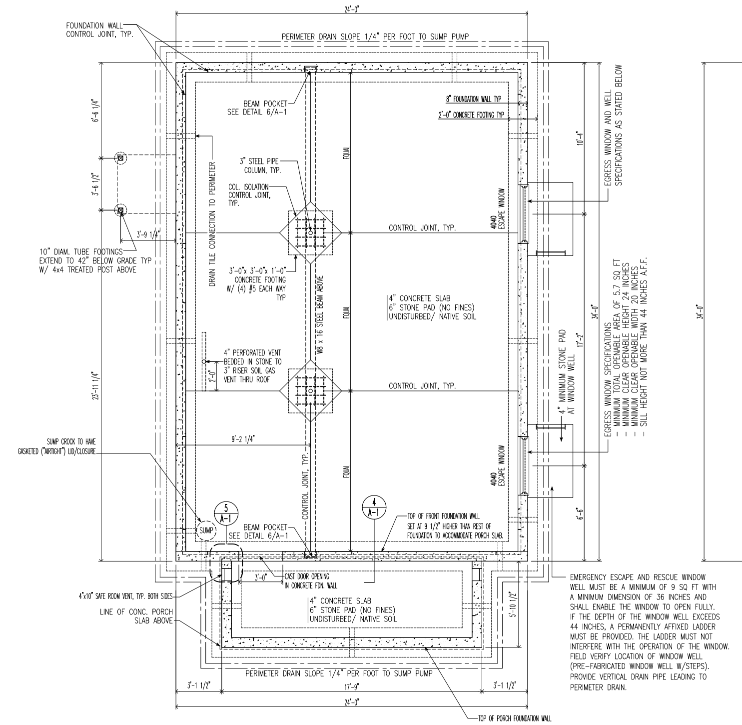
PROJECT:
REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

Notes, Assemblies & Specifications

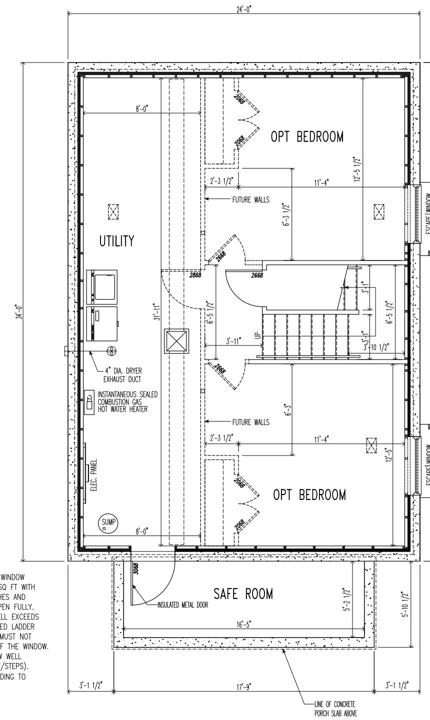
SCALE AS NOTED

A-N

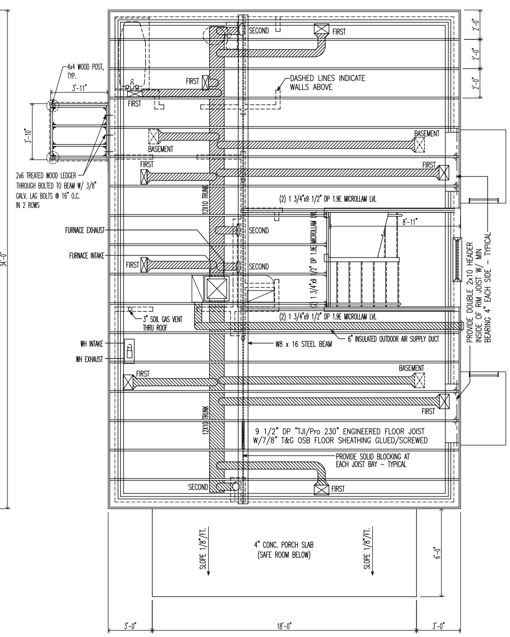
FILE: KS GREENSBURG 1.DWG



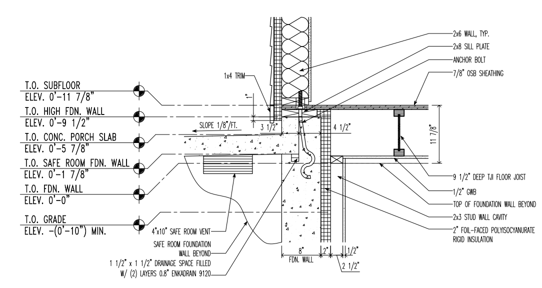
1 | FOUNDATION PLAN
SCALE 1/4" = 1'-0"



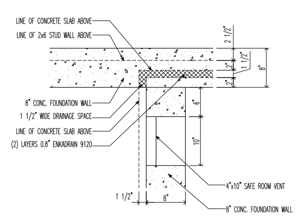
2 | BASEMENT PLAN
SCALE 1/4" = 1'-0"



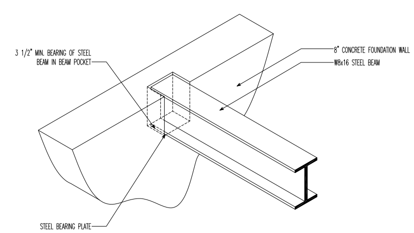
3 | FIRST FLOOR FRAMING PLAN
SCALE 1/4" = 1'-0"



4 | CONCRETE PORCH SLAB / FOUNDATION WALL SECTION DETAIL
SCALE 1" = 1'-0"



5 | FOUNDATION WALL DRAINAGE DETAIL
SCALE 1" = 1'-0"



6 | BEAM POCKET DETAIL
SCALE 1" = 1'-0"

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ARCHITECT:
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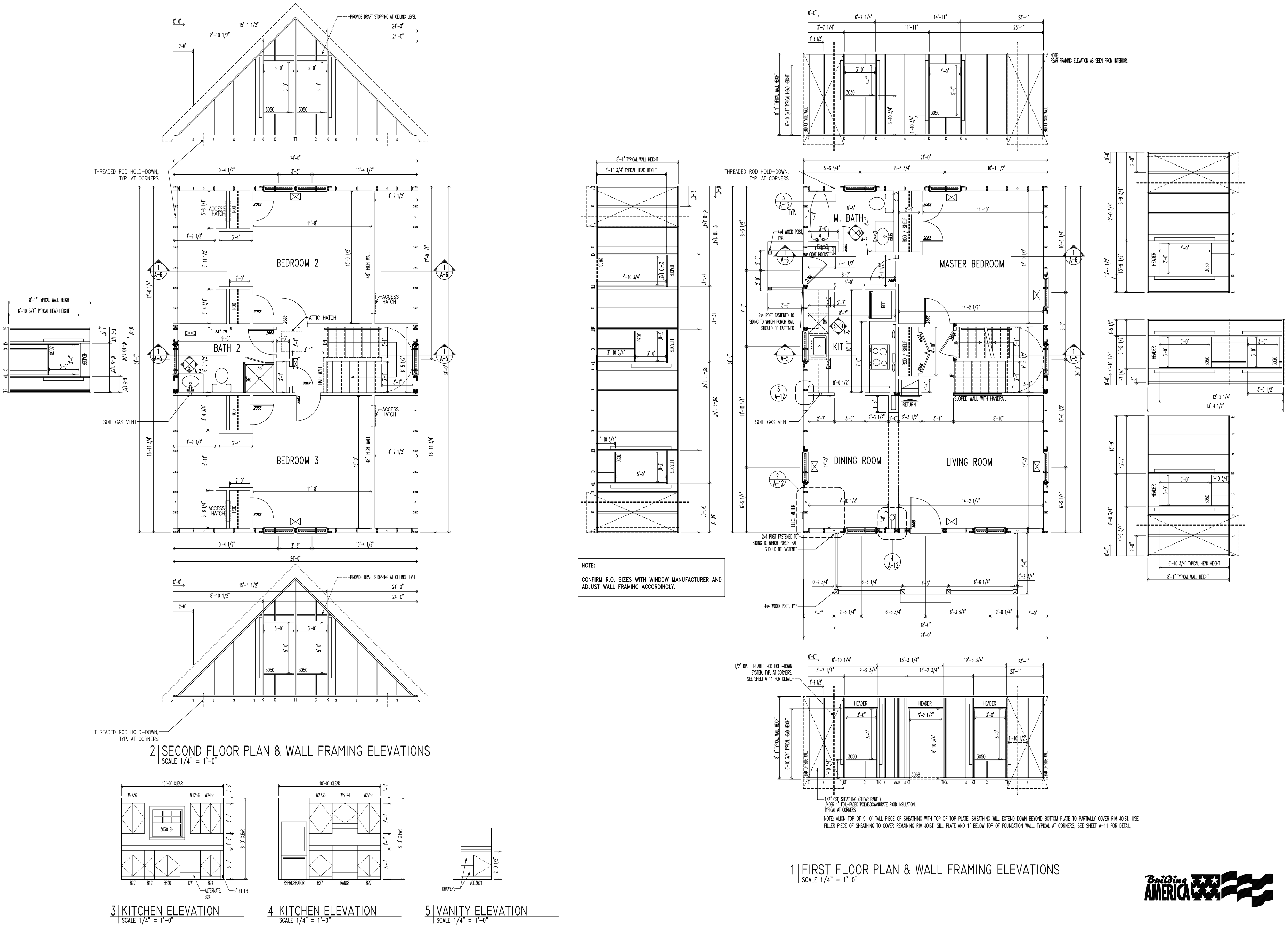
PROJECT:
REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

Foundation Plan, Basement Plan & First Floor Framing Plan & Details

SCALE AS NOTED

A-1

FILE: KS GREENSBURG 1.DWG



2 | SECOND FLOOR PLAN & WALL FRAMING ELEVATIONS
SCALE 1/4" = 1'-0"

1 | FIRST FLOOR PLAN & WALL FRAMING ELEVATIONS
SCALE 1/4" = 1'-0"

3 | KITCHEN ELEVATION
SCALE 1/4" = 1'-0"

4 | KITCHEN ELEVATION
SCALE 1/4" = 1'-0"

5 | VANITY ELEVATION
SCALE 1/4" = 1'-0"

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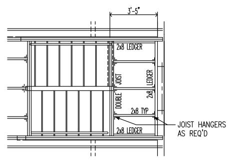
PROJECT:
REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

First & Second Floor Plans, Wall Framing Elevations & Cabinet Elevations

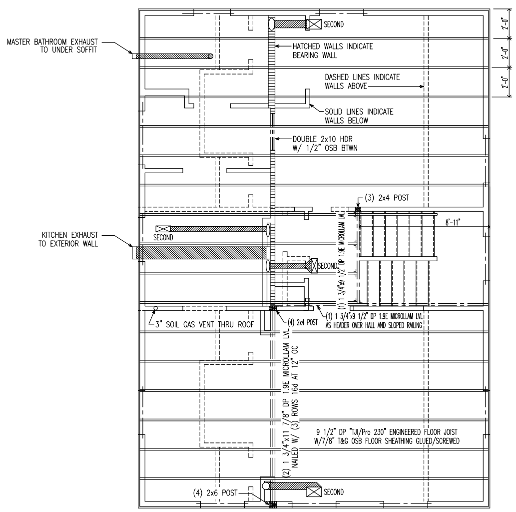
SCALE AS NOTED

A-2

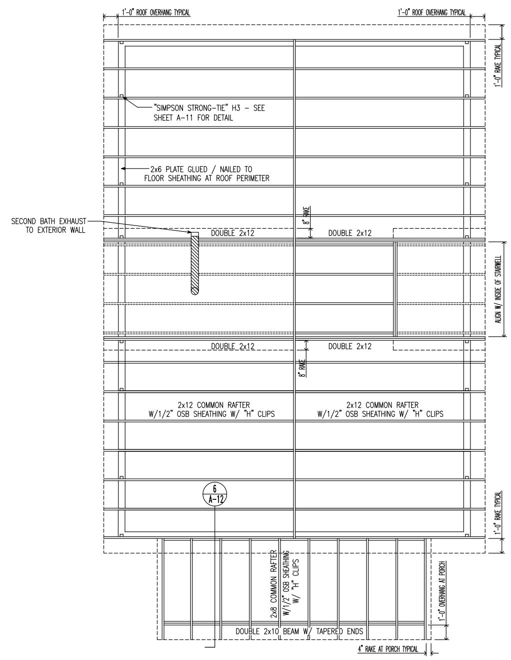
FILE: KS GREENSBURG 1.DWG



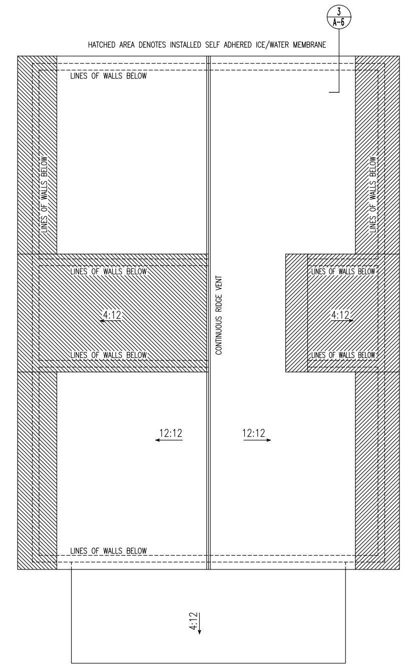
4 | LANDING FRAMING PLAN
SCALE 1/4" = 1'-0"



1 | SECOND FLOOR FRAMING PLAN
SCALE 1/4" = 1'-0"



2 | ROOF FRAMING PLAN
SCALE 1/4" = 1'-0"



3 | ROOF PLAN
SCALE 1/4" = 1'-0"

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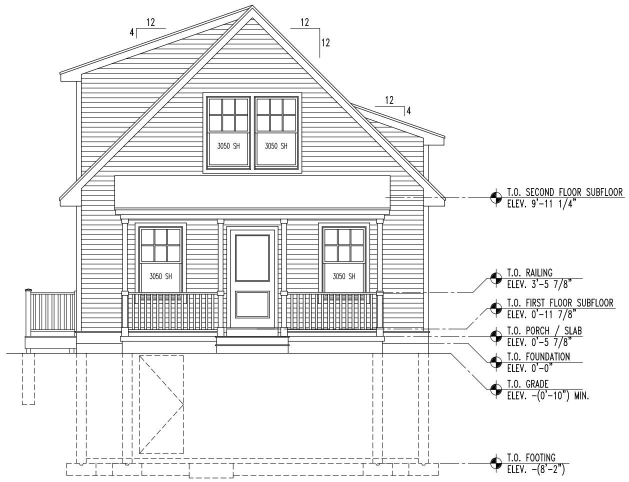
PROJECT:
REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

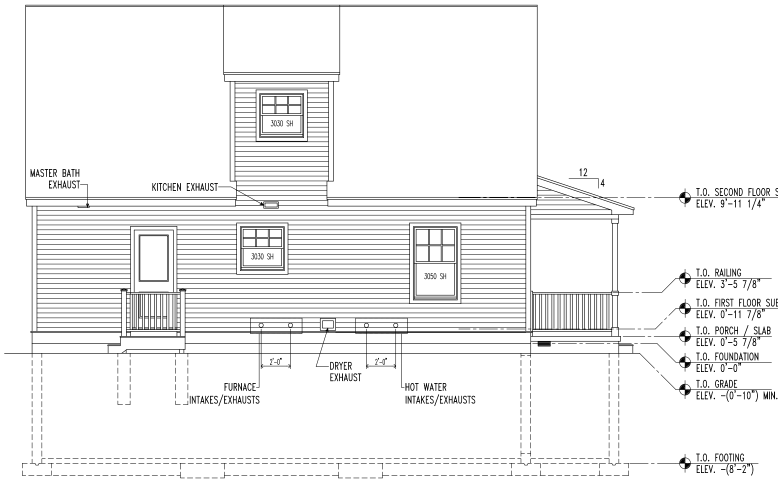
Second Floor Framing Plan, Roof Framing Plan, Roof Plan & Landing Framing Plan
SCALE AS NOTED

A-3

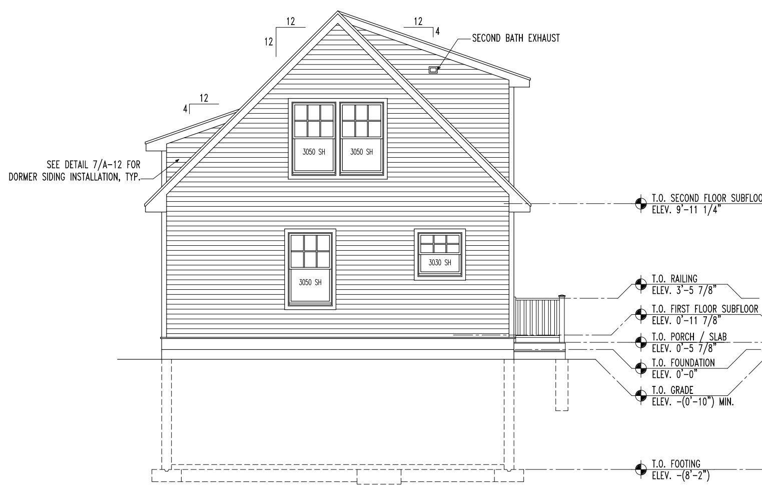
FILE: KS GREENSBURG 1.DWG



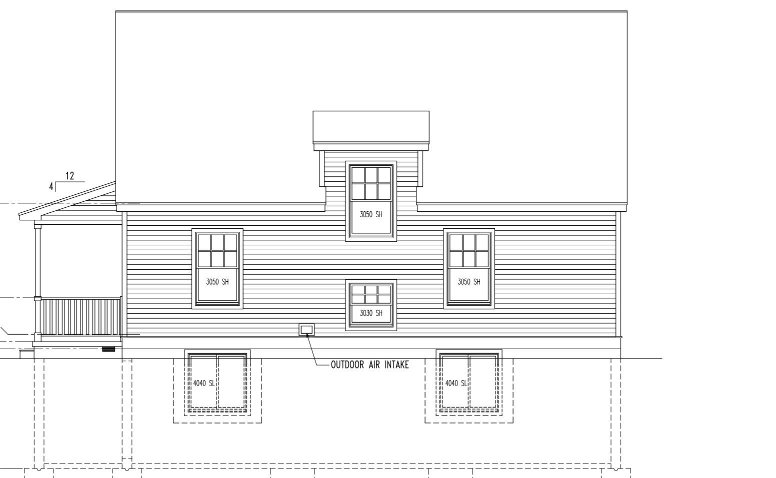
1 | FRONT ELEVATION
SCALE 1/4" = 1'-0"



2 | LEFT SIDE ELEVATION
SCALE 1/4" = 1'-0"



3 | REAR ELEVATION
SCALE 1/4" = 1'-0"



4 | RIGHT SIDE ELEVATION
SCALE 1/4" = 1'-0"

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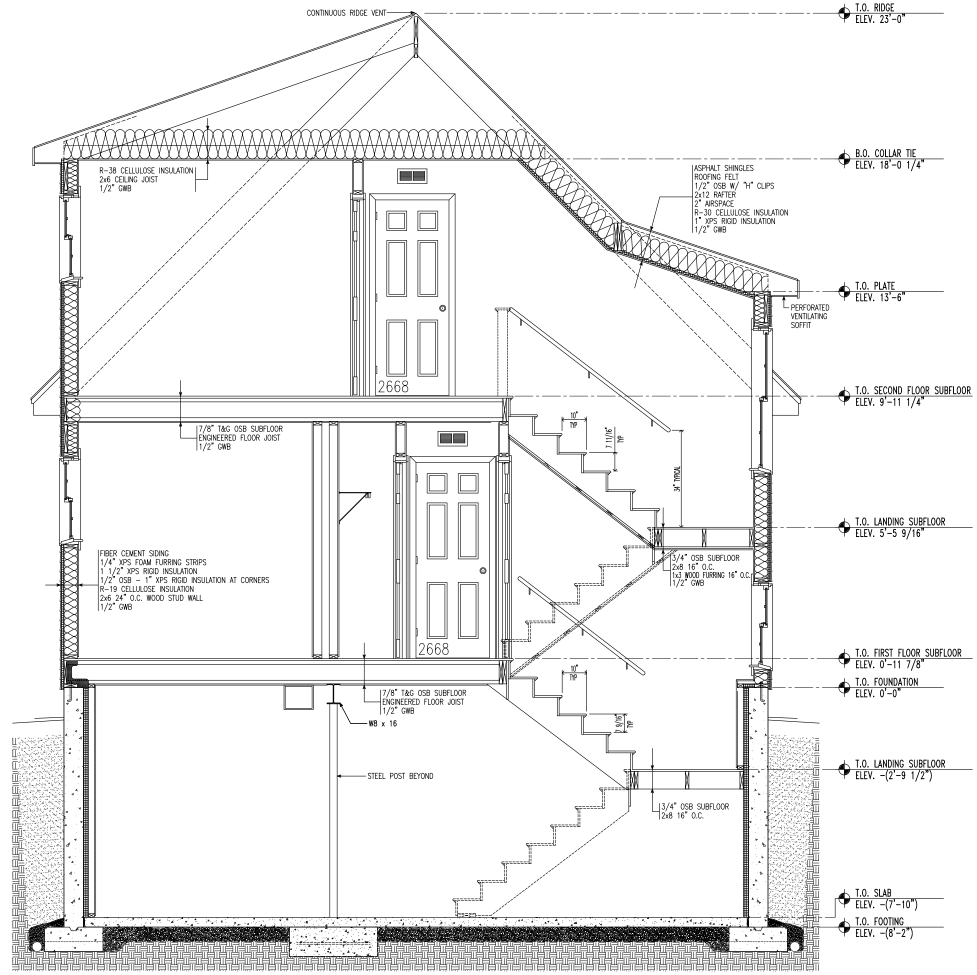
PROJECT:
REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

Building Elevations

SCALE AS NOTED

A-4

FILE: KS GREENSBURG 1.DWG



1 | BUILDING SECTION
SCALE 1/2" = 1'-0"

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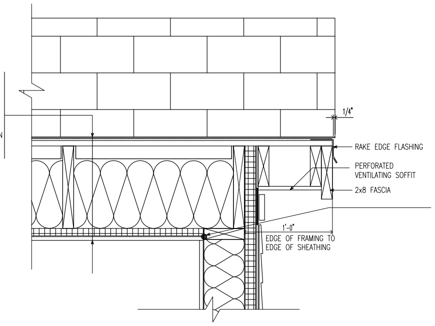
PROJECT:
REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

Building Section

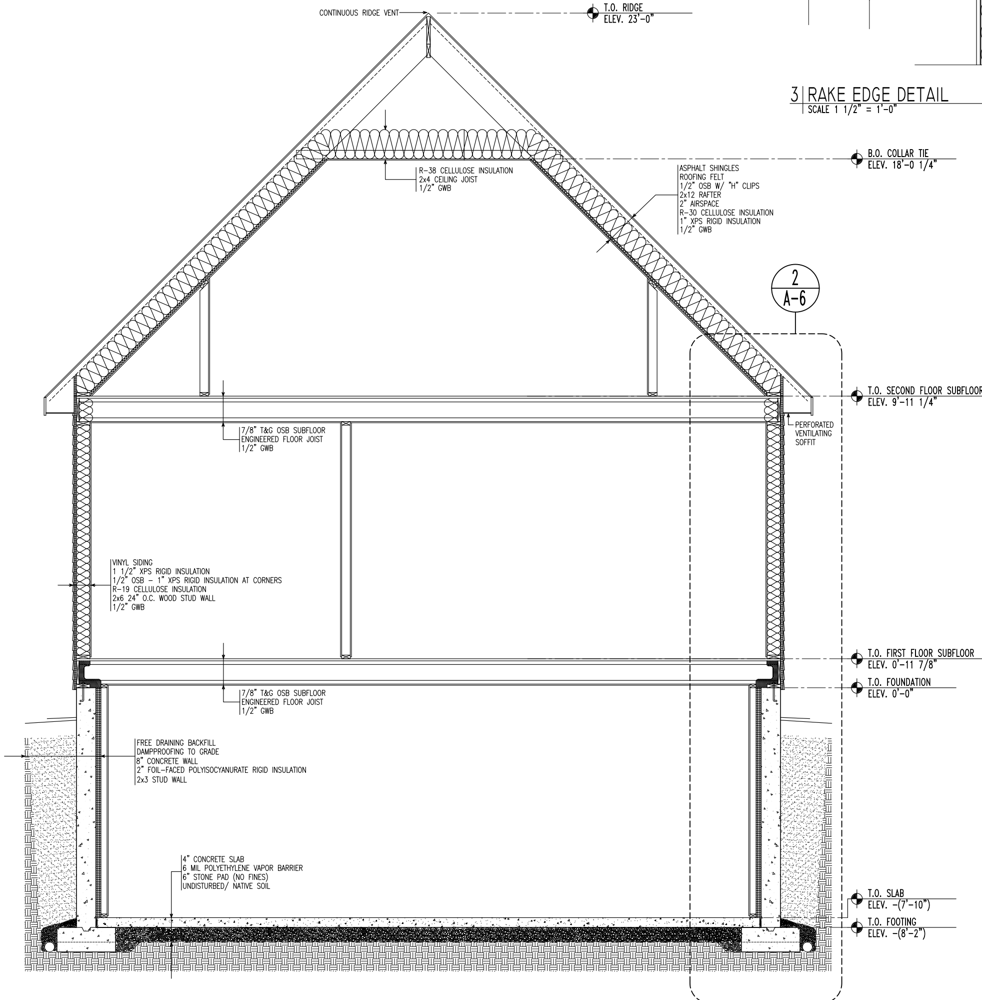
SCALE AS NOTED

A-5

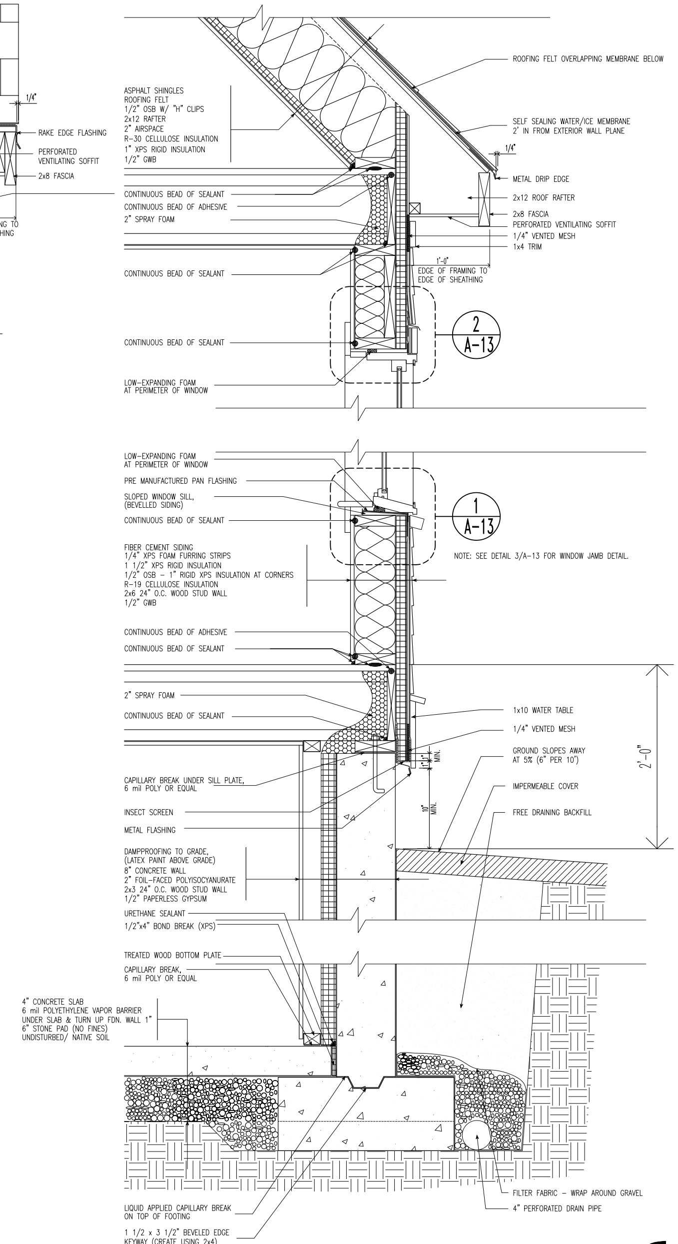
FILE: KS GREENSBURG 1.DWG



3 | RAKE EDGE DETAIL
SCALE 1 1/2" = 1'-0"



1 | BUILDING SECTION
SCALE 1/2" = 1'-0"



2 | WALL SECTION
SCALE 1 1/2" = 1'-0"

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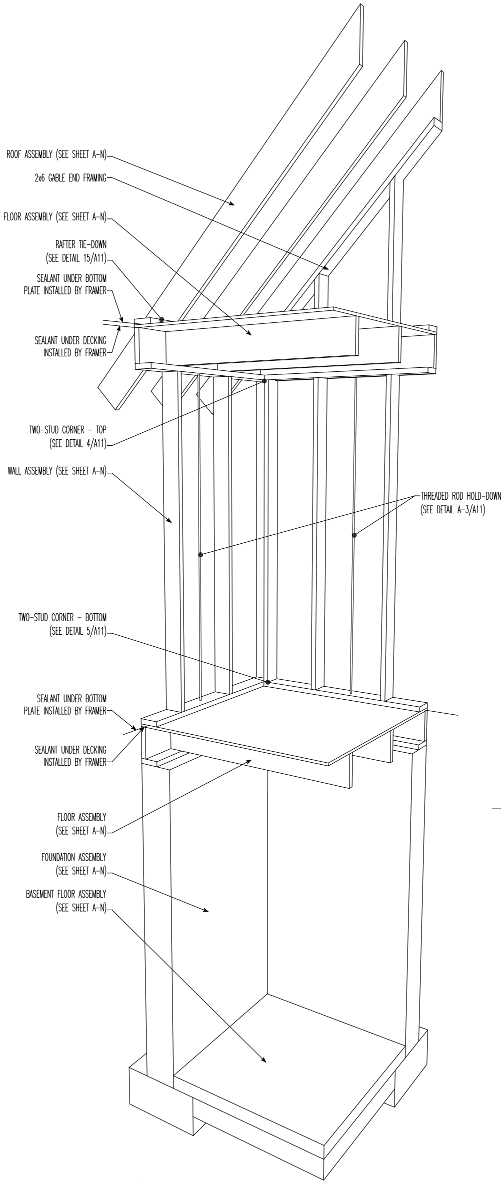
PROJECT:
REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

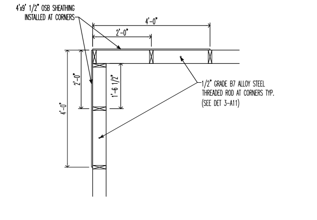
Building Section & Wall Section
SCALE AS NOTED

A-6

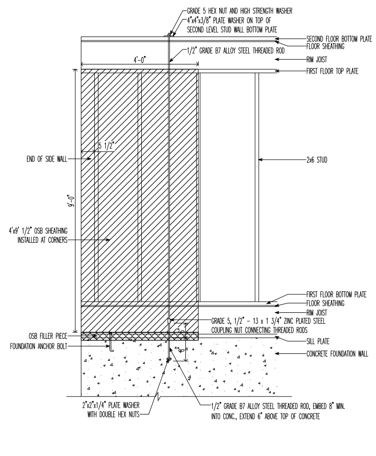
FILE: KS GREENSBURG 1.DWG



1 | FRAMING OVERVIEW
N.T.S.



2 | TYPICAL CORNER FRAMING
N.T.S.



3 | TYPICAL THREADED ROD TIE-DOWN
N.T.S.

ADVANCED FRAMING IRC 2003 REFERENCES

SINGLE TOP PLATE

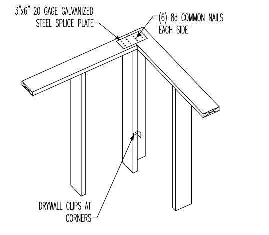
- IRC 2000 and 2003, in Section R602.3.2 Top Plate: Exception: A single top plate may be installed in stud walls, provided that the plate is adequately tied at joints, corners, and intersecting walls by a minimum 3-inch-by-6-inch by 0.036 inch-thick (76 mm by 152 mm by 0.914 mm) galvanized steel plate that is nailed to each wall or segment of wall by six 8d nails on each side, provided that the rafters or joists are centered over the studs with a tolerance of no more than 1 inch (25.4 mm). The top plate may be omitted over lintels that are adequately tied to adjacent wall sections with steel plates or equivalent as previously described.
- IRC 2000 and 2003, in Figure 602.3(2): The figure label states "single or double top plate."
- IRC 2000 and 2003, in Section R602.5: Interior, nonbearing walls shall be permitted to be constructed with 2-inch-by-3-inch (51 mm by 76 mm) studs spaced 24 inches (610 mm) on center or, when not part of a braced wall line, 2-inch-by-4-inch (51 mm by 102 mm) flat studs spaced at 16 inches (406 mm) on center. Interior, nonbearing walls shall be capped with at least a single top plate. Interior, nonbearing walls shall be fireblocked in accordance with Section R602.8.
- IRC Table R602.3(1): For top or sole plate to stud (end nail), two 16d fasteners are required.

NO HEADERS IN NON-LOAD-BEARING WALLS

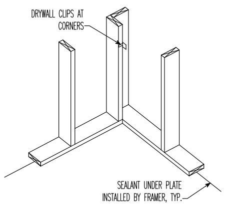
- IRC 2000 and 2003, Section R602.7.2: Nonbearing walls. Load-bearing headers are not required in interior or exterior nonbearing walls. A single, flat 2-inch-by-4-inch (51 mm by 102 mm) member may be used as a header in interior or exterior nonbearing walls for openings up to 8 feet (2438 mm) in width if the vertical distance to the parallel nailing surface above is not more than 24 inches (610 mm). For such nonbearing headers, no cripples or blocking is required above the header.
- IRC 2000 and 2003 Table R702.3.5 Minimum Thickness and Application of Gypsum Board: Allows the use of 24-inch-on-center framing for fastening gypsum board with either fasteners or adhesive 1/2 inch thickness or greater.
- IRC 2000 and 2003 Section R703 Exterior Covering: Structural sheathing and siding requirements are based on Table R703.4. Note that footnote "a" specifies that the table is based on 16 inches on center and that studs-spaced-24-inches-on-center siding shall be applied to sheathing approved for that spacing.
- IRC 2003 Section R602.10.2 Seismic Design Category D2: In Seismic Design Category D2, cripple walls shall be braced in accordance with Table R602.10.1.

DRYWALL CLIPS

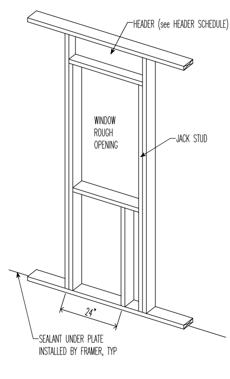
- IRC 2000 and 2003, Section R602.3 Design and Construction: Exterior walls of wood-frame construction shall be designed and constructed in accordance with the provisions of this chapter and Figures R602.3(1) and R602.3(2) or in accordance with AF and PA's NDS. Components of exterior walls shall be fastened in accordance with Table R602.3(1) through R602.3(4). [Excerpt]
- IRC 2000 and 2003, Figure R602.3(2): Note: A third stud and/or partition intersection backing studs shall be permitted to be omitted through the use of wood back-up cleats, metal drywall clips, or other approved devices that will serve as adequate backing for the facing materials.



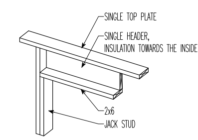
4 | TWO-STUD CORNER - TOP
N.T.S.



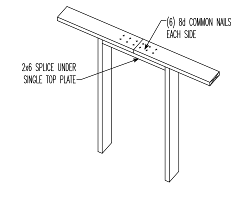
5 | TWO-STUD CORNER - BOTTOM
N.T.S.



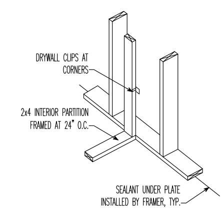
6 | LOAD-BEARING WALL OPENING
N.T.S.



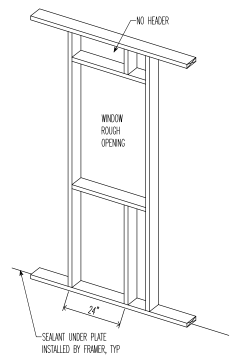
7 | SINGLE HEADER
N.T.S.



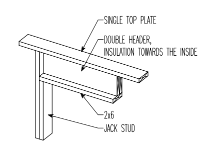
8 | SINGLE TOP PLATE SPLICE
N.T.S.



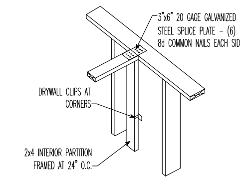
9 | BOTTOM PLATE AT PARTITION
N.T.S.



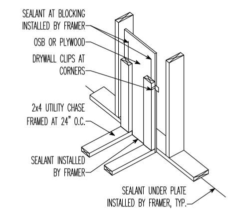
10 | NON-LOAD-BEARING WALL OPENING
N.T.S.



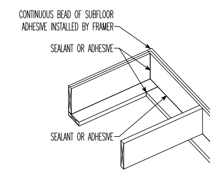
11 | DOUBLE HEADER
N.T.S.



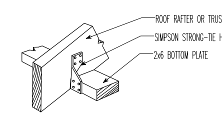
12 | SINGLE TOP PLATE AT PARTITION
N.T.S.



13 | AIR SEALING AT MECH CHASE
N.T.S.



14 | RIM JOIST AIR SEALING
N.T.S.



15 | ROOF-WALL FRAMING CONNECTION
N.T.S.

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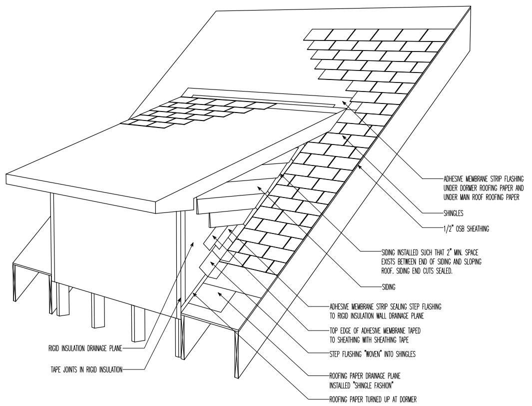
PROJECT: REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

Advanced Framing Details

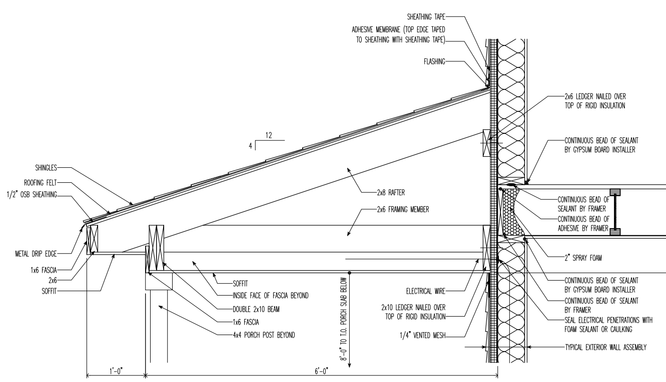
SCALE AS NOTED

A-11

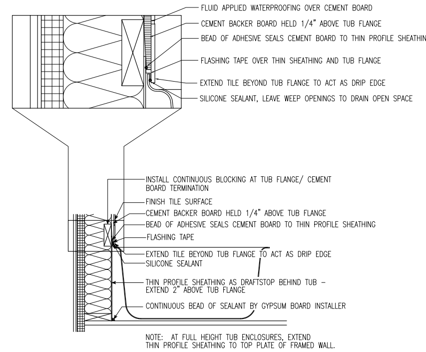
FILE: KS GREENSBURG 1.DWG



7 | DORMER SIDING INSTALLATION
SCALE N.T.S.

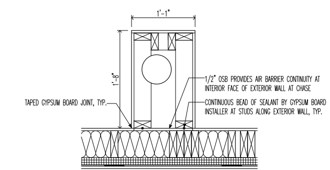


6 | SHED ROOF AT EXTERIOR WALL
SCALE 1" = 1'-0"

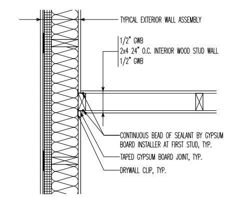


NOTE: AT FULL HEIGHT TUB ENCLOSURES, EXTEND THIN PROFILE SHEATHING TO TOP PLATE OF FRAMED WALL.

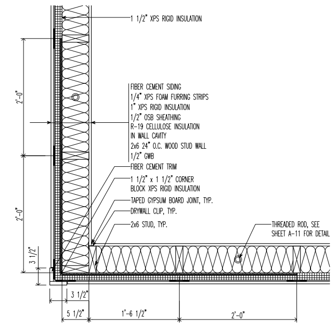
5 | EXTERIOR WALL AT BATHTUB / SHOWER
SCALE 1" = 1'-0"



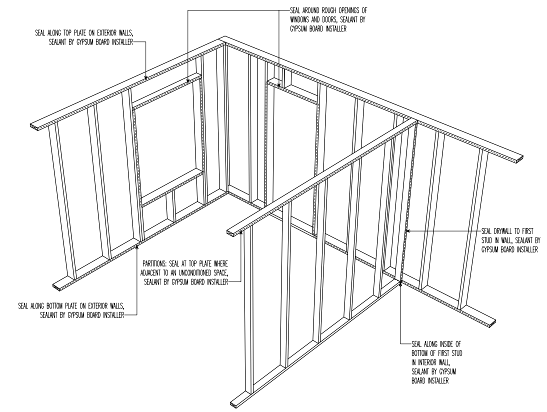
4 | MECHANICAL CHASE AT EXTERIOR WALL
SCALE 1" = 1'-0"



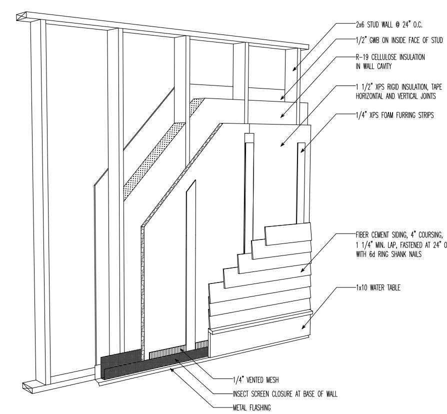
3 | INTERIOR WALL AT EXTERIOR WALL
SCALE 1" = 1'-0"



2 | 2 STUD CORNER AT EXTERIOR WALL
SCALE 1" = 1'-0"



1b | AIR BARRIER AT WALLS AND CEILINGS PERSPECTIVE
SCALE N.T.S.



1a | ENCLOSURE ASSEMBLY
SCALE N.T.S.

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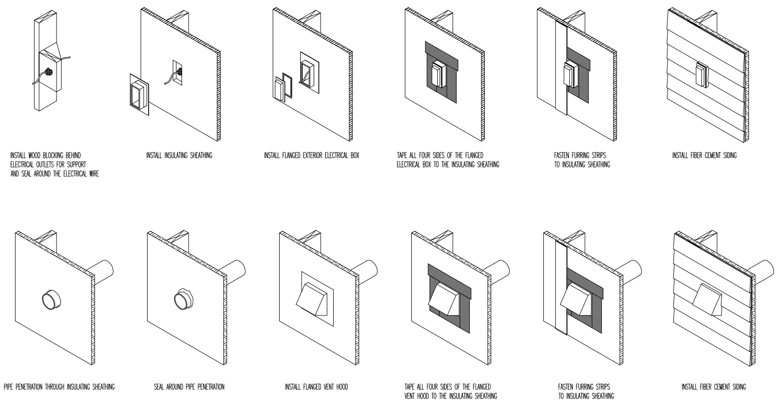
PROJECT:
REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

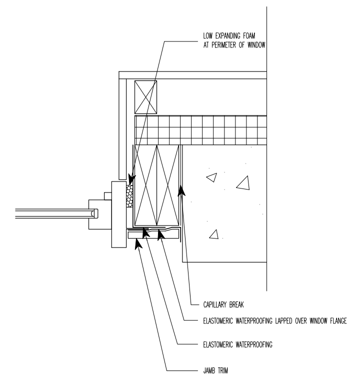
Enclosure Details
SCALE AS NOTED

A-12

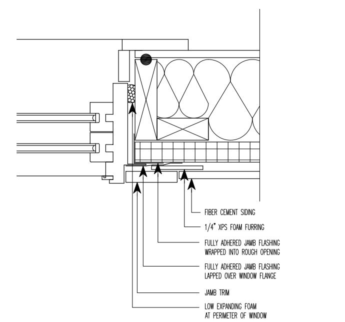
FILE: KS GREENSBURG 1.DWG



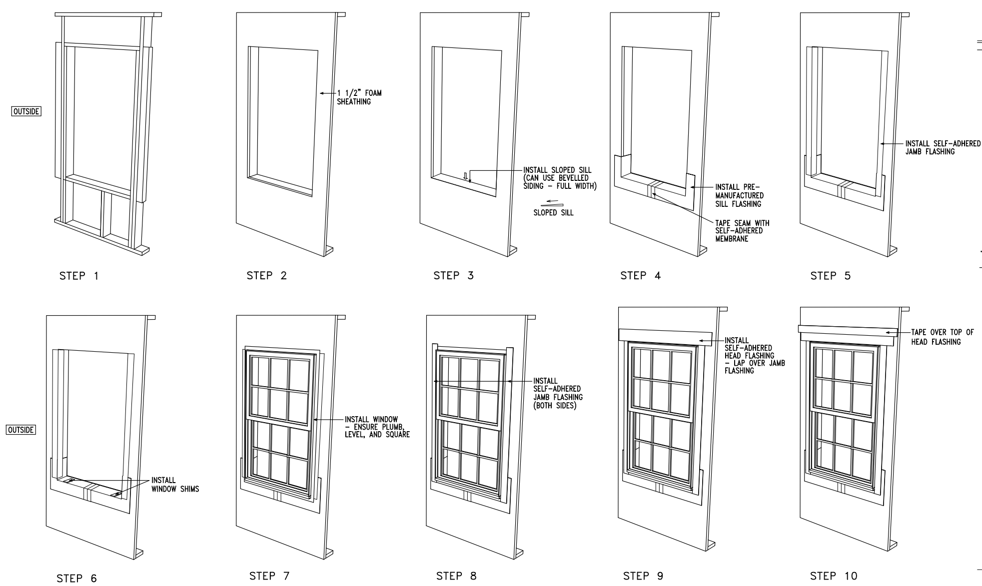
5 | MECHANICAL PENETRATION DETAILS
SCALE NTS



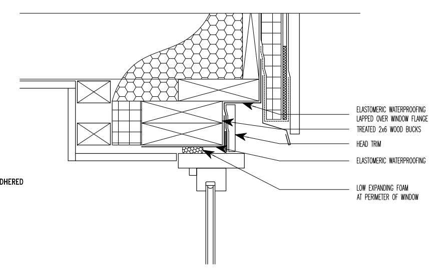
8 | BASEMENT WINDOW JAMB DETAIL
SCALE 3" = 1'-0"



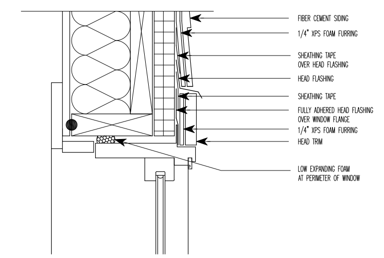
3 | WINDOW JAMB DETAIL
SCALE 3" = 1'-0"



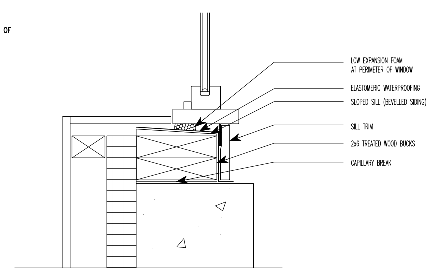
4 | WINDOW INSTALLATION DETAILS
SCALE NTS



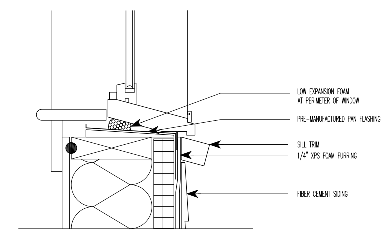
7 | BASEMENT WINDOW HEAD DETAIL
SCALE 3" = 1'-0"



2 | WINDOW HEAD DETAIL
SCALE 3" = 1'-0"



6 | BASEMENT WINDOW SILL DETAIL
SCALE 3" = 1'-0"



1 | WINDOW SILL DETAIL
SCALE 3" = 1'-0"

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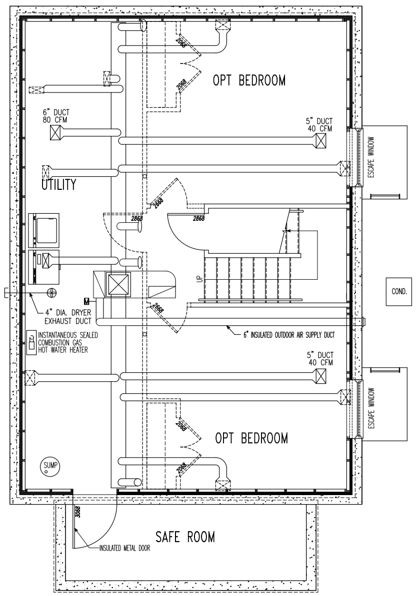
PROJECT:
REBUILDING GREENSBURG, KS
PLAN 1 - THREE BEDROOM HOUSE
MIXED-HUMID CLIMATE

Window, Door & Mechanical Penetration Details

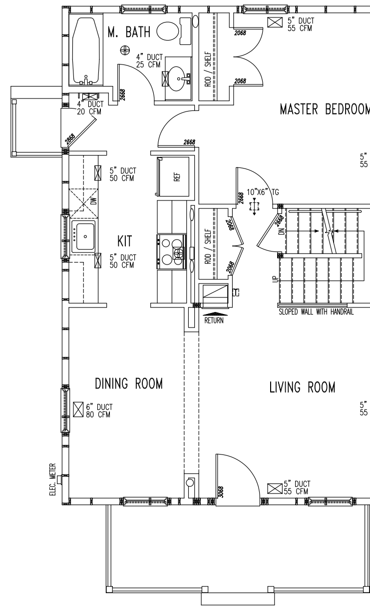
SCALE AS NOTED

A-13

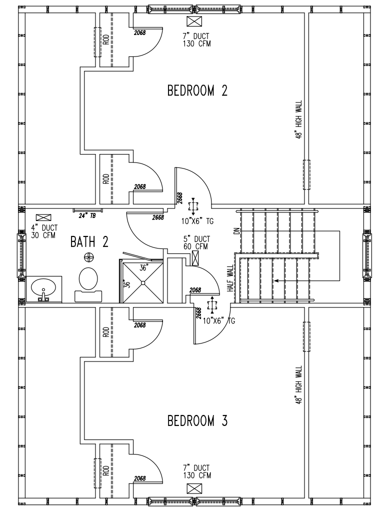
FILE: KS GREENSBURG 1.DWG



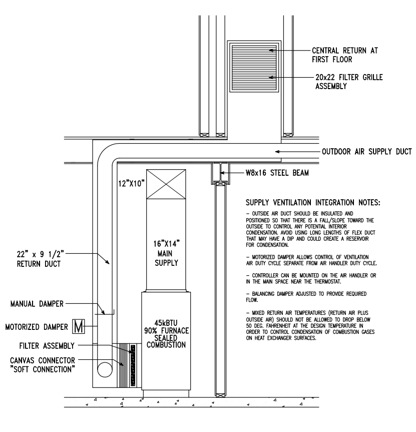
1 | BASEMENT REGISTER FLOWS
SCALE 1/4" = 1'-0"



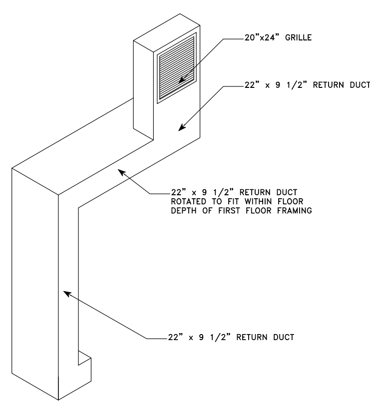
2 | FIRST FLOOR REGISTER FLOWS
SCALE 1/4" = 1'-0"



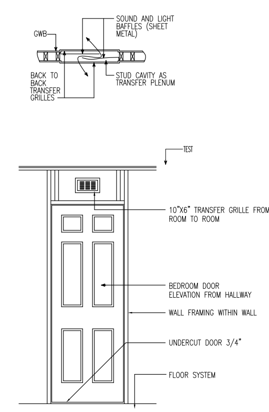
3 | SECOND FLOOR REGISTER FLOWS
SCALE 1/4" = 1'-0"



4 | AIR HANDLER DETAIL
SCALE 1/2" = 1'-0"



5 | RETURN DUCT ISOMETRIC
SCALE 1/2" = 1'-0"



6 | TRANSFER GRILLE OVER DOOR DETAIL
SCALE 1/2" = 1'-0"

NOTES:

1. ALL DUCTS TO BE SEALED WITH MASTIC AND LOCATED IN CONDITIONED SPACE.
2. ALL REGISTERS TO BE ADJUSTABLE DIRECTIONAL MOUNTED WITH DAMPER.
3. TRANSFER GRILLES PROVIDE PRESSURE RELIEF / PRESSURE EQUALIZATION BETWEEN CLOSED ROOMS AND COMMON AREAS (SEE 6/M-1).
4. DOORS TO BE UNDERCUT 3/4" BETWEEN TOP OF FINISH FLOOR AND UNDERSIDE OF DOOR.
5. AIR HANDLER LOCATED AND ACCESSED WITHIN INTERIOR CONDITIONED SPACE.
6. RETURN DUCTED WITH TWO OFFSETS TO REDUCE SOUND AND VIBRATION.
7. A FILTER WITH A MERV 12 RATING SHALL BE INSTALLED AT THE AIR HANDLER.
8. OUTSIDE AIR PROVIDED TO RETURN SIDE OF SYSTEM WITH DAMPER CONTROL.
9. 6" DIAMETER INSULATED OUTSIDE AIR DUCT FROM EXTERIOR SHALL BE INSTALLED WITH A MANUAL DAMPER TO SET FLOW.

LEGEND	
⊠	SUPPLY REGISTER
	OVER DOOR TRANSFER GRILLES
⊕	TOILET EXHAUST FAN, PANSONIC FV-05VFL1
	KITCHEN EXHAUST FAN W/ LIGHT
T	THERMOSTAT
M	MOTORIZED DAMPER FOR O.A. CONTROL
	MANUAL DAMPER
	RETURN AIR FLOW

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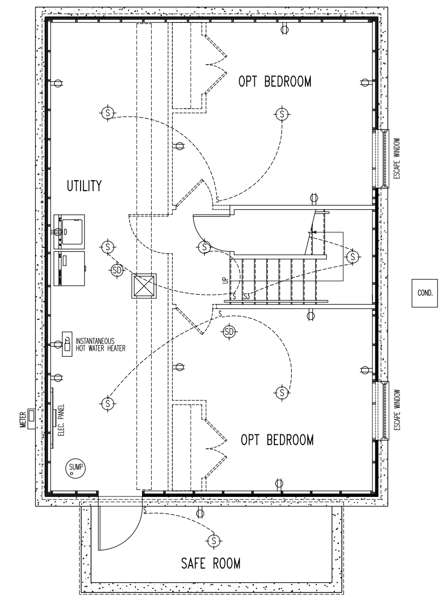
MIXED-HUMID CLIMATE

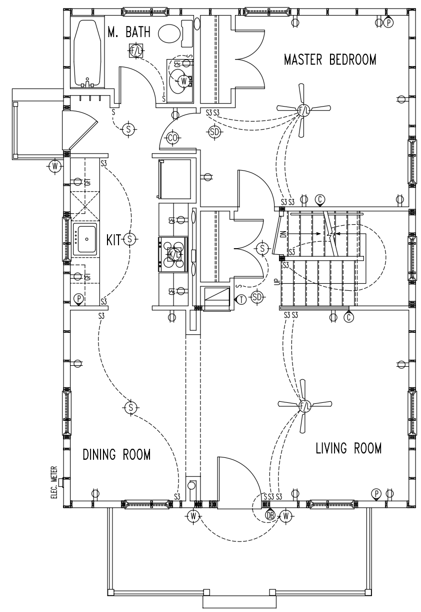
Mechanical Duct Layout, Notes & Details
SCALE AS NOTED

M-1

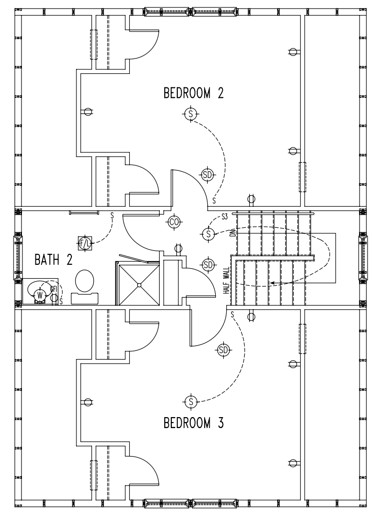
FILE: KS GREENSBURG 1.DWG



1 | BASEMENT ELECTRICAL PLAN
SCALE 1/4" = 1'-0"



2 | FIRST FLOOR ELECTRICAL PLAN
SCALE 1/4" = 1'-0"



3 | SECOND FLOOR ELECTRICAL PLAN
SCALE 1/4" = 1'-0"

ELECTRICAL LEGEND

SYMBOL	DESCRIPTION
S	SURFACE MOUNTED LIGHT FIXTURE
W	WALL MOUNTED LIGHT FIXTURE
D	DROPPED LIGHT FIXTURE
R	RECESSED LIGHT FIXTURE
RA	RECESSED LIGHT FIXTURE (AIRTIGHT)
RW	RECESSED LIGHT FIXTURE (WATERPROOF)
P	POLE LAMP (EXTERIOR-SITE)
F	FLOOD W/MOTION SENSOR
SD	SMOKE DETECTOR (INTERCONNECTED W/ BATTERY BACKUP)
CO	CARBON MONOXIDE DETECTOR (INTERCONNECTED W/ BATTERY BACKUP IF NEC.)
F	EXHAUST FAN
F/L	EXHAUST FAN / LIGHT COMBINATION
K/L	KITCHEN EXHAUST FAN / LIGHT COMBINATION
(24)	FLOURESCENT STRIP LIGHT (SINGLE) (LENGTH IN INCHES)
(24)	FLOURESCENT STRIP LIGHT (DOUBLE) (LENGTH IN INCHES)
(24)	TRACK LIGHT (LENGTH IN INCHES)
C	CABLE TV / PHONE OUTLET
DB	DOOR BELL
T	THERMOSTAT
	110 VAC DUPLEX OUTLET
	110 VAC DUPLEX OUTLET (TOP SWITCHED)
GFI	110 VAC DUPLEX OUTLET (GROUND FAULT INTERUPTOR)
WP	110 VAC DUPLEX OUTLET (WATERPROOF)
	DRYER OUTLET
	RANGE OUTLET
S	SINGLE POLE SWITCH
S3	THREE-WAY SWITCH
S4	FOUR-WAY SWITCH
SD	SWITCH WITH DIMMER
SD3	THREE-WAY SWITCH WITH DIMMER
SD4	FOUR-WAY SWITCH WITH DIMMER
ST	SWITCH WITH TIMER
F	CEILING FAN
F/L	CEILING FAN/LIGHT COMBINATION
ACCU	AIR COOLED CONDENSING UNIT
AHU	AIR HANDLING UNIT

NOTE: ALL SYMBOLS MAY NOT BE USED IN PLAN

NOTES:

1. 20A 220V CIRCUIT TO CONDENSER UNIT.
2. 20A 120V CIRCUIT TO AHU.
3. ALL WORK MUST COMPLY WITH MOST RECENT VERSION OF THE NATIONAL ELECTRIC CODE.

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MIXED-HUMID CLIMATE

Electrical Plans

SCALE AS NOTED

E-1

FILE: KS GREENSBURG 1.DWG

B.10 Fact Sheet: Energy Efficient Homes are More Affordable than Conventional Homes

National Renewable Energy Laboratory

Energy Efficient Homes are More Affordable than Conventional Homes

As part of its technical support of the rebuilding effort in Greensburg, NREL has evaluated the cost and performance tradeoffs associated with adding energy performance upgrades to new homes. The results of this evaluation indicate that Greensburg residents can use savings in utility bills to pay for improvements in energy efficiency of new homes. Because of the relatively high cost of energy in Greensburg, the increase in annual mortgage payments for energy upgrades, when financed as part of a 30 year mortgage, can be offset by the corresponding savings in annual utility bills.

Table 1 - Estimated Annual Cost Savings: Greensburg 30% Energy Savings Target

	Greensburg: 30% Savings
Estimated Incremental First Cost for Energy Upgrades that Provide 30% Savings Relative to Standard Practice[1]	$4,000
Annual Amortized Cost for Energy Upgrades (7%, 30Year mortgage)[2]	$211
Estimated Annual Utility Bill Savings	$723
Net Annual Savings	*$512*

A detailed summary of specific recommendations for improvements in energy efficiency that are cost effective in Greensburg is included in Appendix XX. The recommendations include packages that will produce energy savings of 30%, 40% and 50% beyond the current minimum Greensburg code. Because of the large annual savings in utility bills from energy efficiency upgrades, other approaches for financing energy efficiency upgrades can also be considered.

[1] Evaluated relative to minimum IECC 2003. 2000 ft2, 2-story, 16% window to floor area ratio, unconditioned basement.
[2] Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage. Federal tax credits not included.

Energy Efficient Homes are more Durable than Conventional Homes

Energy efficient homes not only reduce homeowner utility bills, they are also designed to be more durable than conventional homes. Current designs for high performance walls, roofs, windows, and foundation systems include increased protection from moisture damage. "Peel and stick" materials are used to seal roofs and windows, and attention to flashing, drainage, and drying details from roof to foundation ensure that water drains quickly away from the building so that the building can dry out quickly.

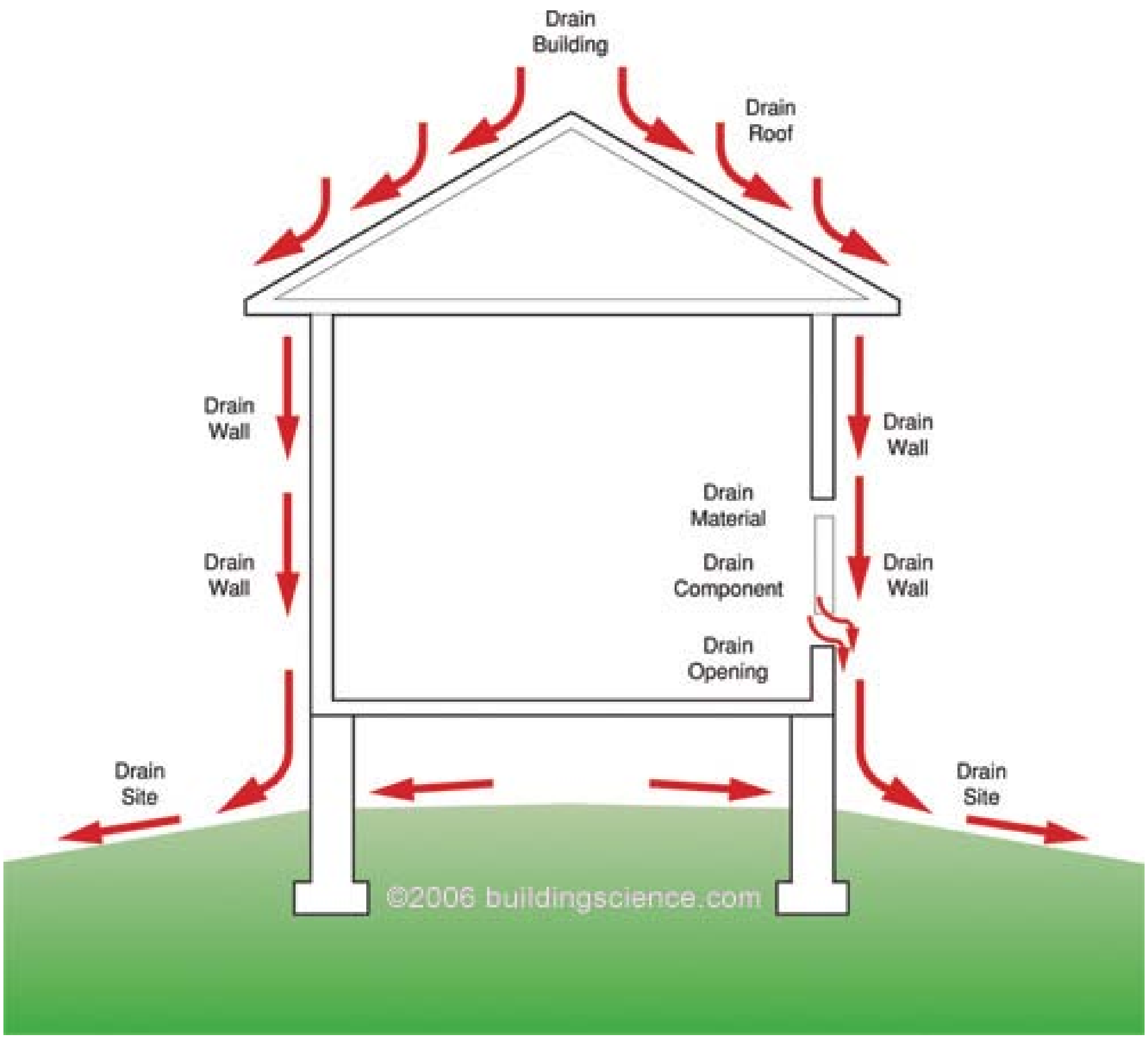

Figure 1 - Moisture Control in High Performance Homes. More information on specific design details and example building plans can be found on, **http://www.buildingamerica-greensburg.com/**

Additional Savings from Peak Cooling Demand Reductions in Energy Efficient Homes

In addition to providing overall benefits in terms of annual energy savings, energy efficient homes also reduce the amount of electric power required to meet peak cooling loads compared to conventional homes, allowing reduced investments in backup power systems required to meet peak electric demand. Assuming an average installed cost for a diesel generator of about $1000/kW, each kW of reduced electric demand produced by energy efficiency upgrades in new homes potentially translates into $1000 in savings for the Greensburg municipal utility.

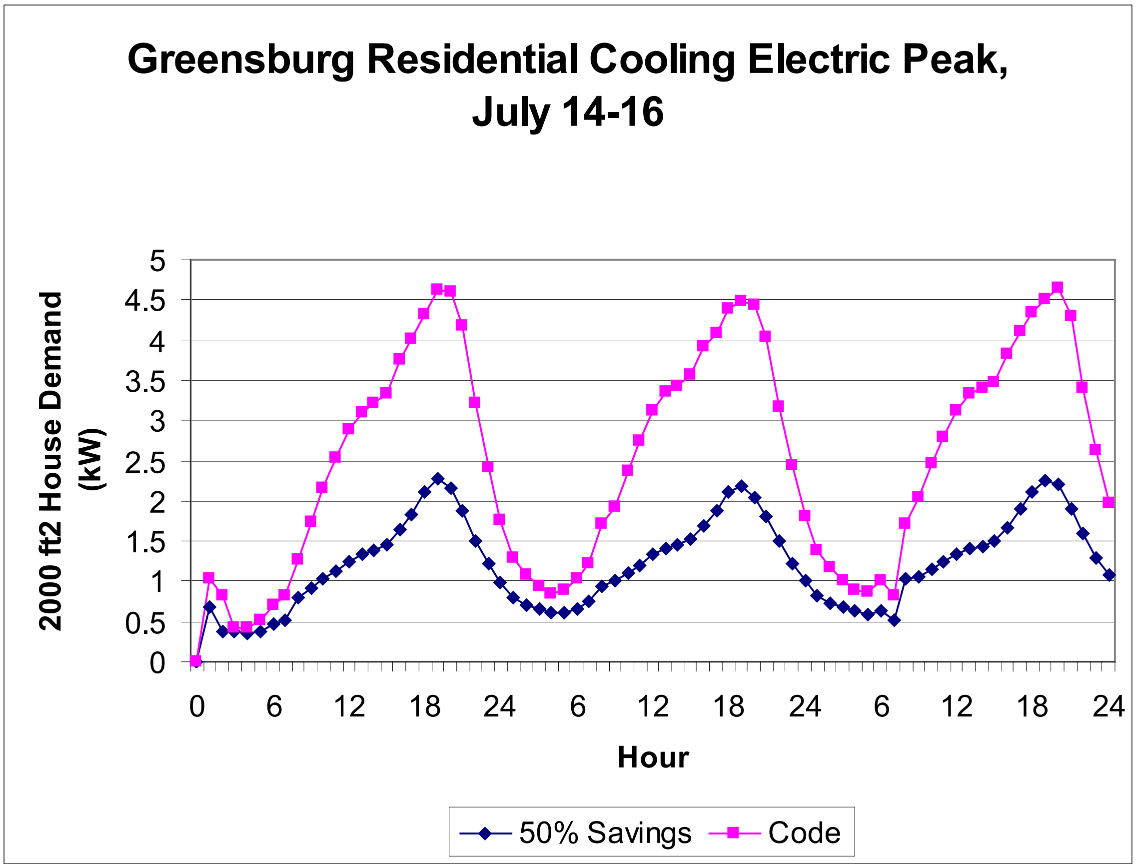

Figure 2 – Peak Demand Savings From Energy Efficient Homes. A home designed to reduce energy use by 50% compared to a conventional home also reduces peak electric demand by about 2kW.

Additional Resources and Case Studies for Designing and Building Energy Efficient Homes in Greensburg

CASE STUDIES

Building Greensburg:

http://buildingamerica-greensburg.com

Mixed-Humid Climate Construction Details:

www.buildingscience.com/housesthatwork/mixedhumid/atlanta.htm

www.buildingscience.com/housesthatwork/mixedhumid/charlotte.htm

www.buildingscience.com/housesthatwork/mixedhumid/louisville.htm

http://www.buildingscience.com/buildingamerica/casestudies/fairburn/default.htm

RESIDENTIAL RENEWABLE ENERGY RESOURCES

Primer on Photovoltaics:

www.buildingscience.com/resources/misc/BSC_PV_Primer.pdf

Best Practices: Volume 6, High Performance Home Technologies: Solar Thermal and Photovoltaic Systems:

www.eere.energy.gov/buildings/building_america/pdfs/41085.pdf

GENERAL RESOURCES

Builder's Guide to Mixed-Humid Climates:

www.buildingsciencepress.com

EEBA Water Management Guide:

www.eebga.org/bookstore

Building America Performance Targets:

www.buildingscience.com/buildingamerica/targets.htm

International Energy Conservation Code (IECC) Climate Zones:

www.energycodes.gov/implement/pdfs/color_map_climate_zones_Mar03.pdf

DOE Climate Zones by County:

www.eere.energy.gov/buildings/building_america

Houses That Work II:

www.buildingscience.com/housesthatwork

Building Materials Property Table:

www.buildingscience.com/housesthatwork/buildingmaterials.htm

Building Science Glossary:

www.buildingscience.com/resources/glossary.htm

SITE: DRAINAGE, PEST CONTROL, AND LANDSCAPING

Pest Control:

www.uky.edu/Ag/Entomology/entfacts/efstruc.htm

FOUNDATION: MOISTURE CONTROL AND ENERGY PERFORMANCE

Radon Resistant Construction Practices (EPA Radon Control Web Site):

www.epa.gov/iaq/radon/construc.html

Borate-Treated Rigid Insulation:

www.buildingscience.com/buildingamerica/casestudies/fairburn/default.htm

MECHANICALS/ELECTRICAL/PLUMBING

HVAC System Sizing (ACCA Manual J and Manual D):

www.buildingscience.com/resources/mechanical/hvac/509a3_cooling_system_sizing_pro.pdf

Mechanical Ventilation Integrated with HVAC System Design:

www.buildingscience.com/resources/mechanical/hvac/advanced_space_conditioning.pdf

Transfer Grilles:

www.buildingscience.com/resources/mechanical/hvac/transfer_grille_detail.pdf

www.buildingscience.com/resources/mechanical/hvac/transfer_grills.htm

Indoor Humidity:

www.buildingscience.com/resources/moisture/relative_humidity_0202.pdf

Whole House Dehumidification System:

www.buildingscience.com/resources/mechanical/hvac/residential_dehumidification.pdf

Air Conditioning Best Practices:

www.buildingscience.com/resources/mechanical/air_conditioning_equipment_efficiency.pdf

High-Energy Efficiency Major Appliances:

www.eere.energy.gov/EE/buildings_appliances.html

BUILDING ENCLOSURE: MOISTURE CONTROL AND ENERGY PERFORMANCE

Design Using Advanced Framing Methods:

www.buildingscience.com/housesthatwork/advancedframing/default.htm

Air Sealing Details:

www.buildingscience.com/housesthatwork/airsealing/default.htm

"Insulations, Sheathings, and Vapor Diffusion Retarders"

www.buildingscience.com/resources

Solar Driven Moisture in Wall Assemblies:

www.buildingscience.com/resources/walls/solar_driven_moisture_brick.htm

Solar Driven Moisture in Roof Assemblies:

www.buildingscience.com/resources/roofs/unvented_roof.pdf

Window Flashing:

EEBA Water Management Guide (www.eeba.org/bookstore)

COMMISSIONING

SNAPSHOT (Short Non-Destructive Approach to Provide Significant House Operation Thresholds) Form:

www.buildingscience.com/buildingamerica/snapshot_form.pdf

www.buildingscience.com/buildingamerica/snapshot_instructions.pdf